TAMPERE UNIVERSITY OF TECHNOLOGY

TIMO VUORELA

STREAMLINING SPARE PART INVENTORY MANAGEMENT IN A MULTI-ECHELON NETWORK OF SERVICE BUSINESS

Master of Science Thesis

Prof. Jarkko Rantala has been appointed as the examiner at the Council Meeting of the Faculty of Business and Technology Management on 7th March 2012.

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
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The research question of this thesis is: How could spare part inventory management of Cargotec Services be streamlined and unified? The motive behind this thesis was to strengthen Cargotec's service business by creating common policies and by optimizing the tied up capital in the stocking network while providing suitable service level. The first target was to examine and describe the existing inventory management process. The second objective was to create guidelines for analyzing front line inventories and for determining inventory assortments at different levels. The final objective was to define how inventory management performance should be measured in future.

This thesis is a mix of action oriented research and case study. The first step of the thesis was to create a theoretical framework which would be the foundation for developing and unifying inventory management policies of Cargotec Services. In this part of the thesis, scientific journals and literature were used as source material. The second part of this thesis is the empirical study. This part was begun by examining inventory management processes of both central and case front line unit. The present processes were defined by observation, interviewing responsible personnel, and examining internal documents. After the current processes were examined and described, the streamlining framework was constructed. The framework was based on the theoretical context, interviews, statistics, and benchmarking.

This thesis presents a framework for streamlining inventory management process. The framework consists of different guidelines and instructions. The first guideline is for analyzing local item activity. Locally active items are divided into items that need to be stocked locally and items that should be stocked only centrally. Conversely, locally non-active items should be divided into returnable and non-returnable items. The study provides also guidelines for forming strategic stock in the network and performance measurements for inventory management in future. Besides the inventory management streamlining, Cargotec Services should also measure and develop performance of suppliers, haulers, and warehousing service providers. Cooperation and information sharing between different parties should be enhanced by interaction, communication, and exploitation of the new information system and collaboration tools.

TIIVISTELMÄ

TAMPEREEN TEKNILLINEN YLIOPISTO
Tuotantotalouden koulutusohjelma
VUORELA, TIMO: Varaosien varastonhallinnan virtaviivaistaminen monitasoisessa huoltoverkostossa
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Tämän diplomityön tutkimuskysymys oli: Kuinka Cargotec Oyj:n Services-yksikön varaosien varastonhallintaa voitaisiin virtaviivaistaa ja yhtenäistää? Työn tavoitteena oli vahvistaa Cargotecin huoltoliiketoimintaa luomalla yhteiset varastonhallinnan toimintaperiaatteet sekä optimoimalla toimitusverkoston varastoihin sitoutunut pääoma heikentämättä kuitenkaan palvelutasoa. Ensimmäisenä osatavoitteena oli tutkia ja kuvata nykyinen varastonhallintaprosessi. Toisena osatavoitteena oli luoda ohjeistus tytäryhtiöiden varastoinnin virtaviivaistamiseen ja varaosalajitelman suunnitteluun toimitusketjun eri tasoilla. Lisäksi tavoitteena oli määrittää kuinka varastonhallinnan suorituskykyä tulisi mitata jatkossa.

Tämä diplomityö oli toiminta-analyyttisen tutkimuksen ja case-tutkimuksen yhdistelmä. Työn ensimmäinen osuus koostui kirjallisuuskatsauksesta, jota käytettiin perustana varastonhallintamenetelmien kehittämiselle ja yhtenäistämiselle. Työn toinen vaihe oli empiirinen tutkimus, joka alkoi nykyisten varastonhallintaprosessien mallintamisella. Prosessit määriteltiin haastattelujen, dokumenttien, ja havainnoinnin avulla. Kun nykyprosessit oli selvitetty, kehitettiin toimintamalli varastojen ja varastonhallinnan virtaviivaistamiseksi. Malli muodostettiin kirjallisuuskatsauksen, haastattelujen, sisäisten raporttien ja dokumenttien analysoinnin sekä benchmarkingin avulla.

Tämä työ esittelee toimintamallin varastonhallinnan virtaviivaistamiseen. Malli koostuu muun muassa toimintasuosituksista ja -ohjeistuksista. Ensimmäinen ohjeistus koskee tytäryhtiöiden varaosalajitelmien aktiivisuuden analysointia. Paikallisesti aktiiviset varaosat jaetaan keskitetysti ja paikallisesti varastoitaviin lajitelmiin. Vastaavasti paikallisesti liikkumattomat varaosat jaetaan palautuskelpoisiin ja romutettaviin varaosiin. Lisäksi työssä esitetään hyväksymisprosessi, jonka avulla voidaan muodostaa strateginen varasto ja säätää sitä manuaalisesti. Työssä esitellään myös ohjeistus varastonhallinnan suorituskyvyn mittaamiseen. Varastonhallinnan virtaviivaistamisen lisäksi Cargotecin tulee mitata ja kehittää toimittajien, kuljetusyritysten, ja operatiivisen varastoinnin suorituskykyä. Myös tiedon jakamista ja eri osapuolten välistä yhteistoimintaa tulisi parantaa huoltoverkostossa. Tässä tulee hyödyntää muun muassa käyttöönottovaiheessa olevaa tietojärjestelmää ja sähköisiä yhteistyösovelluksia.

PREFACE

This Master of Science thesis was made at Cargotec Finland Oy Services in Tampere. The whole thesis process lasted for eight months between December 2011 and July 2012. I started writing the thesis after working six months as a trainee at Services department. Thus, when beginning the thesis, I had already some contacts and knowledge of the business. This work experience made the first steps of the research easier. All in all, making this thesis was an interesting, challenging, and educative process.

First of all, I would like to thank Professor Jarkko Rantala for examining this thesis and for guiding me through the project. At Cargotec, many people have contributed to the creation of this thesis. I would like to thank especially Mr. Seppo Haapala for providing the topic and necessary information for my thesis, for arranging the front line interviews, and for mentoring me during the project. I would also like to acknowledge the help and cooperation of personnel at Cargotec Services' Central Operations and at the front line units. Especially, I want to thank the Logistics team in Tampere.

Furthermore, I am grateful for my family and friends who have supported me during my studies and thesis project.

Tampere, 24th July 2012

Timo Vuorela

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ABBREVIATIONS AND NOTATION

APAC	Asia Pacific.
AS	Cargotec Services' central warehouse in Tampere, Finland.
COGS	Cost of goods sold.
DC	Distribution center.
EDC	European Distribution Center. Cargotec Services' central warehouse in Metz, France.
EMEA	Europe, the Middle East, and Africa.
EOQ	Economic order quantity. A model that identifies the optimal order quantity by minimizing the amount of annual costs which vary with order size.
ERP	Enterprise resource planning. ERP-systems allow companies to integrate and manage their operations and resources.
KIRC	Kalmar Industries Report Central. A web tool for creating reports.
KPI	Key performance indicator.
NDC	Nordic Distribution Center. Cargotec Services' central warehouse in Stockholm, Sweden.
ROP	Reorder point. When the stock level drops to this point or below, a new purchase order will be placed.
RPL	Internal replenishment order from one central warehouse to another.
SKU	Stock-keeping unit. An identification code or number that is given for each unique item in stock.
SMC	Sandvik Mining and Construction.

1. INTRODUCTION

1.1. Research background

There is an expression that it is far easier to keep an existing customer than to get a new one (Richards 2011, p. 229). Thus it is vital to assure that company's current customers do not switch to competitor's services. In spare part business customer satisfaction and service level are closely connected. Customers regularly demand high service level because of the criticality of spare parts. It can be extremely costly to the customer if their machine is out of order because of late spare part delivery. And in many cases these failures in spare part deliveries cause penalties to the service provider and have a negative influence on company's image.

Inventories have always been perceived as a natural part of doing business and a common belief is that it is not possible to carry out business with low inventory levels. In spare part business keeping inventories is essential because of the uncertainty of demand. Despite the fact, it is still reasonable to aim for effective and optimized inventory management because large inventories tie large amounts of company's capital. In addition, stocking of parts does not really increase the added value to the customer. Customers expect good service level, not large inventories. Proper service level is possible to achieve with lower inventory levels when cooperation and information transparency are improved in the supply chain. Large inventories in supply chain are usually a sign of problems and lack of trust between organizations or functions. (Sakki 1999, pp. 90-91.)

In spare part business these two aspects have to be closely examined. On the one side of the scale there are inventory levels and capital invested in inventories, and on the other side there are service level and customer satisfaction. In order to operate spare part business successfully, companies must find balance in this scale by optimizing the spare part inventory management. Minimization of inventories and increase of part availability seem to be two opposite targets but by sophisticated inventory management and effective use of specialized information systems it is possible to achieve them both (Hladík 2011, p. 26). Inventory management optimization is especially relevant in inventory models like Cargotec Services' where there are inventories at various levels of the supply chain. In this kind of situation, it is essential to pay close attention to applied inventory management policies, such as on which level to stock which parts.

1.2. Case company

1.2.1. Cargotec Corporation and its brands

Cargotec is the world's leading provider of cargo handling solutions. Its intention is to improve the effectiveness of cargo flows by offering cargo handling systems and related services for the loading and unloading of goods. Cargotec is a globally operating corporation which has formed through a series of mergers and acquisitions during the past decades. Cargotec Corporation was eventually born through a demerger from KONE in 2005. At that time, Cargotec was also listed to the Helsinki stock exchange. Cargotec employs approximately 11000 persons worldwide. In 2011 Cargotec's global net sales were 3139 million euros and operating profit rose to 207 million euros. (Cargotec 2011a; Cargotec 2012.) Figure 1.1 shows the development of Cargotec sales and operating profit margins.

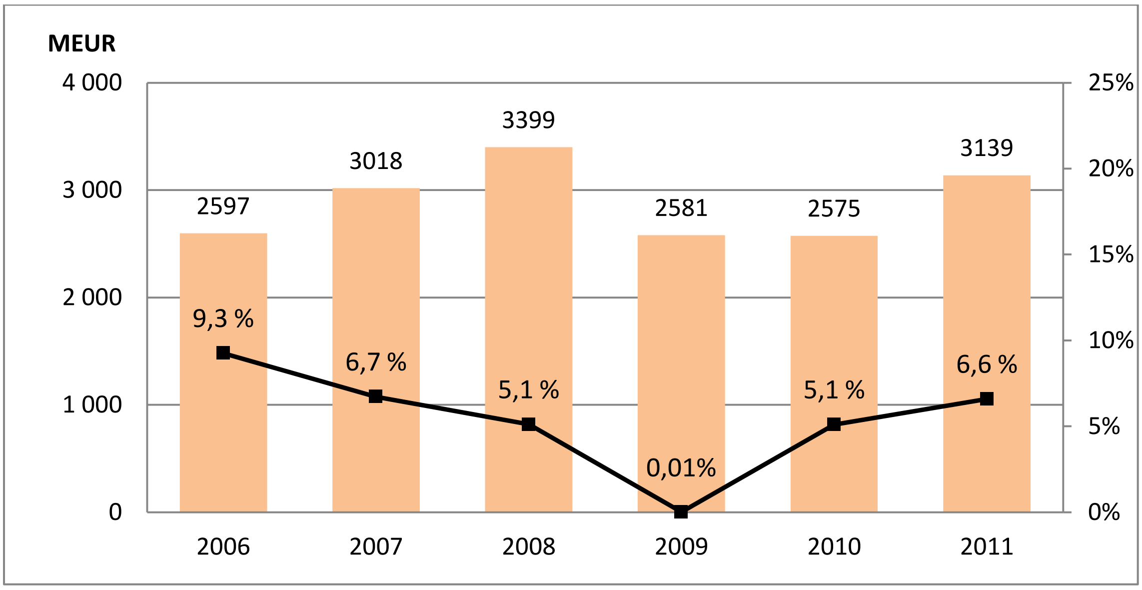

Figure 1.1. *Cargotec's total sales and operating profit margins between 2006 and 2011. (Adapted from Cargotec 2007; Cargotec 2012.)*

Cargotec's key customer groups include for example ship owners, port operators, shipyards, logistics companies, defense forces and heavy industry companies. From the beginning of year 2012, the organization of Cargotec has been divided to four business areas which are Terminals, Load Handling, Marine, and Services. In these business areas, Cargotec has three daughter brands Kalmar, Hiab, and MacGregor. These brands are global market leaders in their own fields. Kalmar brand includes container and heavy material handling solutions. These solutions are used worldwide in ports, terminals, distribution centers, and heavy industry. Hiab is known for the most extensive load handling equipment offering in the industry. Its on-road handling solutions are used in moving goods and materials in many fields, such as construction, industry, forestry, waste handling and defense forces. MacGregor brand includes cargo handling solutions which are used in marine transport and in the offshore logistics. (Cargotec 2011a; Cargotec 2012.)

Cargotec Corporation includes also original equipment manufacturer Bromma which is specialized in spreaders. Bromma's offering includes spreaders for ship-to-shore cranes, mobile port cranes and yard crane spreaders as well as port security solutions. Bromma spreaders are manufactured in Sweden and Malaysia. These spreaders can be found from more than 500 terminals in 90 countries. Cargotec announced also an acquisition of terminal operating systems provider Navis at the end of January 2011. Navis has over 300 employees of which the majority works in the United States and India. By this acquisition Cargotec aims to strengthen its competence to provide total cargo handling solutions for its customers. (Cargotec 2012.)

1.2.2. Cargotec Services

In past years, the significance of service solutions has been increasing in Cargotec's business and it is currently an important mainstay for the company. Cargotec continues to put stronger emphasis on service development and to seek new growth from customers who are outsourcing their service operations. In fact, development of service business has been selected as one of Cargotec's strategic focus areas for the coming years, as shown in figure 1.2. Services business area offers support throughout the customer's supply chain and is responsible for ensuring the uninterrupted operation of customers' equipment over its complete life cycle. The services include for example spare part supply, repair and maintenance, inspections and user support. Cargotec has over 600 sales and service locations worldwide and in fact, one fourth of Cargotec's employees work in maintenance and service. Services' sales increased to 745 million euros in 2011. This equates around 24 percent of the total sales of Cargotec. (Cargotec 2012.)

Figure 1.2. *Cargotec's strategic focus areas for the coming years (Cargotec 2012).*

Services organization is divided into six departments. The spare part inventory management is handled by Parts and Logistics department. The spare part distribution is operated through the Central Operations department and distribution centers (DCs).

Cargotec's spare parts are originally purchased from various suppliers and then delivered to Cargotec Service's DCs. Spare parts are stocked in DCs and then supplied to front line units and then to the end customers.

1.3. Research problem and objectives

The main goal of this thesis is to streamline the spare part inventory management process and unify inventory management policies of Cargotec Services in order to strengthen the service business. This will be done by examining inventory management process of Central Operations as well as the process of one chosen pilot front line unit. One of the main objectives behind this thesis is to be able to optimize the invested capital in inventory while keeping suitable service level to the customers. The thesis aims also to standardize inventory management policies between Cargotec Services' Central Operations and front line units, and thus systematize front lines' inventory management. Thus the research problem of this thesis can be phrased as:

- There is not a common policy for managing inventories in Cargotec Services' supply network and the network carries overlapping inventories.

The research question of this thesis is:

- How could spare part inventory management of Cargotec Services be streamlined and unified?

In order to answer the research question, the following sub-questions must be examined:

- What is the structure of Cargotec's spare part supply chain?
- How are inventories managed and what policies exist at the Central Operations and at the case front line?
- What kind of steps should the streamlining process include?
- How should the front line inventories be analyzed?
- How should the stocking level be determined, that is, which items should be stocked locally and which centrally?
- How to proceed with different item groups that result from the analyses?
- How should inventories be classified and controlled in future?
- How should performance of inventory management be measured in future?

1.4. Scope of research

The thesis concentrates on inventory management and planning process of Cargotec Services in EMEA (Europe, the Middle East, and Africa) region. Thus other regions are not included. Another limitation is that the study concerns only Terminal and Load Handling business areas of Cargotec, which means that Marine business area is excluded. Front line units refer to Cargotec's own sales offices and therefore external dealers and agents are excluded. Because the main focus of this thesis is on spare part inventory management and planning aspects, for example human resources and operational warehousing related aspects are not examined. The focus of streamlining process is on the inventory management of Cargotec’s front line units and DCs. The customer base of chosen front line market is examined as well in order to understand what is expected from the spare part inventories. Hence, supplier performance is excluded from the study. The scope of research is illustrated in figure 1.3.

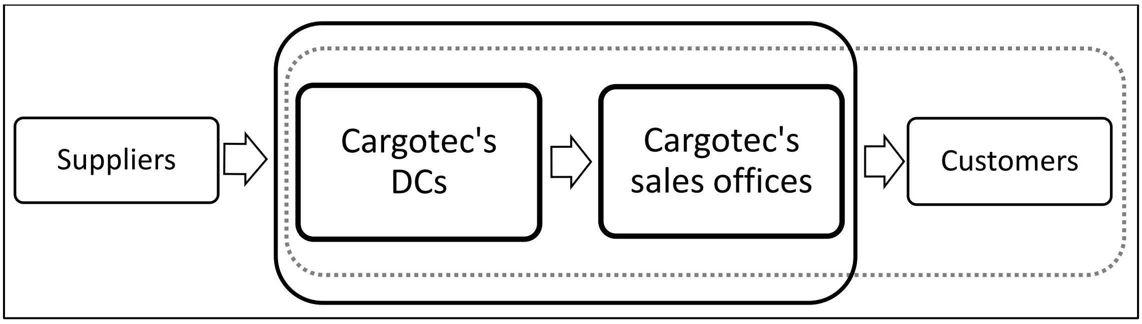

Figure 1.3. *Simplified supply chain of Cargotec’s spare parts and focus of research.*

Transportation costs are not evaluated separately in this study. These costs are taken into account in ordering costs charged from customers. This means that when a customer places an order with spare part lines the transportation costs will be charged with order line costs. Furthermore, examination of different transportation methods is excluded from the study.

1.5. Research approach

The research approach used in this thesis is action oriented research approach. Olkkonen (1993, pp. 72-73) describes that the purpose of action oriented research approach is to try to understand a selected problem by using and combining historical data, relevant theory, and practice. The perception of action oriented research approach is illustrated in figure 1.4. Action oriented research approach is commonly used in studies of organization’s operations where the problem includes both quantitative and qualitative factors. Typically, when a researcher begins this kind of study, there is a lack of external and objective observation that could be used. Thus the researcher must try to understand the process at issue by means of interaction. Interaction between researcher and research subject is thus a common characteristic in action oriented research. In many cases, the results achieved by this research approach cannot be generalized. Thus the results must be critically analysed thoroughly before using them to other or wider research subject.

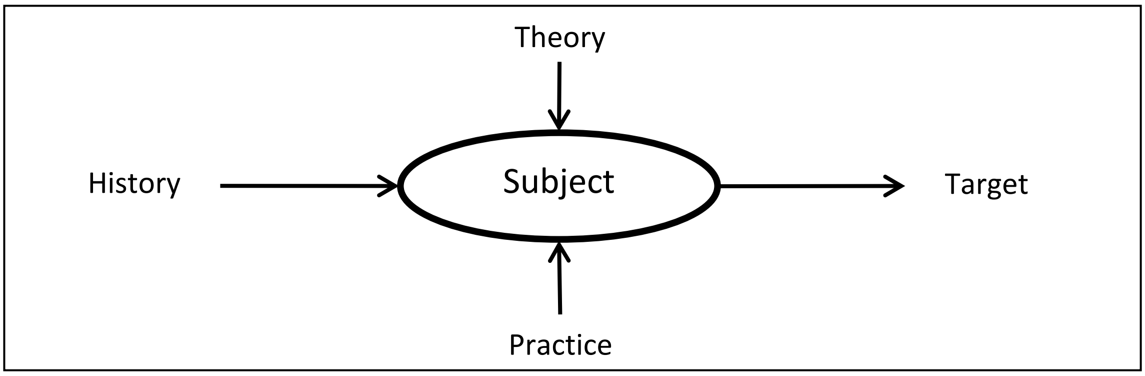

Figure 1.4. *The perception behind action oriented research approach (Olkkonen 1993, p. 75).*

This research has also characteristics of a case study. Hirsjärvi et al. (2007, pp. 130-131) state that a case study includes detailed and intensive information about one specific case or small group of connected cases. The subject of case study is an individual, a group, or a community, and the focus of the study is usually on the processes. The relationship between subject and its environment is also in significant role. In case study, the objective is to describe phenomena by using various methods of information collection, such as observation, interviews, and document research.

1.6. Structure and research methods of this thesis

The structure of this thesis is divided into two parts. The first part of the thesis consists of two theoretical chapters which establish a framework for the study. This part is not compiled only to provide new ideas for the empirical part but also to introduce the basic theory of inventory management for Services organization. This is done because one important goal of the thesis is to systematize front line inventory management, and thus it is important to learn the basics of inventory management first. Data of this section is collected from scientific journals and literature. The first chapter of this section is chapter two which consists of general information about spare part business such as definition of spare parts and the special characteristics of spare part business and logistics. This chapter introduces also multi-echelon spare part inventory systems. Chapter three presents relevant inventory management theory. The chapter includes theory about inventory costs, stock types, and inventory management methods such as item classification, replenishment, and performance indicators.

The rest of the thesis forms the empirical section. This section begins with chapter four which introduces the current spare part process of Cargotec Services. This chapter will also be the starting point for the streamlining process. The next chapter presents the results of benchmarking interviews that were carried out during the research process. Chapter six presents the results of this study which include for instance phases and guidelines of the streamlining process. In this chapter, also key performance indicators are determined. Chapter seven is the final chapter of this thesis and it presents the conclusions of the study.

In this study, various research methods were used. According to Saunders et al (2009, pp. 151-152), methods of data collection and analysing can be divided into two main categories which are quantitative and qualitative methods. The primary difference between these two is the focus on numeric and non-numeric data. Quantitative methods can be described as the data collection techniques or analyzing procedures which generate or use numerical data. Numerical data can be for example graphs or statistics. Conversely, qualitative methods, such as interviews, are techniques which generate or use non-numerical data. In research, it is also possible to combine these methods, which was the case in this study. The data of the empirical chapters was collected from internal interviews, documents, and statistics. Benchmarking and observation were used as well.

In the empirical part of this research, one of the main sources of data was internal interviews. Olkkonen (1993, p. 105) mentions that interviews provide qualitative data which is generally less objective than quantitative data. Most interviews provide data which consists of personal opinions but after all, they are in important role when describing the actual situation and condition of the subject at hand. Hirsjärvi et al. (2007, p. 201) state that interviews include many sources of data distortion. Errors can derive from the interviewer or from the interviewee. Also the interviewing situation can cause data distortion. Thus it is important to plan interviews well. Interviews of this research were carried out as half-structured which means that the themes and questions can change depending on the progress of the discussion (Saunders et al. 2009, p. 321).

Also benchmarking was utilized in the thesis. The purpose was to identify best practices and to get new ideas from external points of comparison. According to Lecklin (1999, p. 177) and Randall (2003, p. 194), benchmarking refers to an external focus on internal activities, functions, or operations. A benchmark can be created at any level and in any functional area of an organization. In benchmarking, the purpose is first to understand existing processes and then to identify an external reference point by which each activity can be measured. The objectives of benchmarking include recognizing and learning better practices, defining target levels, finding new methods, and eliminating prejudice.

The empirical part includes also statistical data and reports which are an output from enterprise resource planning (ERP) system. Olkkonen (1993, pp. 104-105) writes that when using seemingly precise statistics, it is important to realize that the data is still usually based on approximation and it is not always equivalent to truth. This can result from differences in concept definitions or from constantly changing environment. Researcher must try to find the sources and consequences of errors. Errors derive especially in data collection phase. Errors can result from factors such as unclear instructions, misunderstandings, defective statistics, and misjudgment. One of the most important factors is the delay and obsolescence of statistics. In case of this thesis, the available inventory statistics change constantly. Thus the used statistics are only approximations of the real situation of Cargotec's inventories.

In the modelling and describing of Cargotec Services' processes, some data was collected by participative observation. Hirsjärvi (2007, p. 209) state that with observation, researcher can get immediate and direct information about activity of individuals, groups, or organizations. Observation can be divided into two types which are participative or systematic. Participative observation is less systematic and organized than systematic observation. Participative observation can form freely in the situation and the observer is participates to the activity of group. In most cases, it is a method of qualitative research.

2. SPARE PART BUSINESS

2.1. Definition of spare parts

Technical installations and equipment are subject to planned maintenance and repair in failure situations. In most maintenance and repair cases, pieces of equipment are needed to replace the defective parts. These are commonly known as spare parts. (Fortuin & Martin 1999, p. 950.) Buker (2001, p. 1089) defines spare parts as parts which are used to maintain products or equipment which the firm sells. Spare parts are also known as service parts or spares. Spare part inventory can be kept at the production location or at distributors, service locations, or other locations close to serviced customers.

Gopalakrishnan and Banerji (2004, p. 232) have defined spare part as part which is similar to the one that needs to be replaced from the equipment because of wear and tear during the operating life of the equipment. First of all, spare parts include materials such as pipes, tubes, springs, wires, hoses, and knobs. Secondly, spare parts can be sub-assemblies of the necessary parts of equipment like engines, compressors, and alternators. Thirdly, spare parts can also be complete units, such as pumps and gears, which are installed to the machine. Spare parts can appear to be smaller and cheaper than the capital products but they are in a vital role in maintaining and reinforcing any equipment's reliability.

Botter and Fortuin (2000, p. 657) have divided spare parts into two groups which are repairables and consumables. Repairable parts are parts that can be swapped into new ones and sent to a repair center in failure situation. So these parts are technically and economically repairable. Conversely, consumables are not technically or economically repairable. In failure situation, these parts are replaced by a new one and scrapped. Driessen et al. (2010, p. 5) have made the same classification but they use terms repairable parts and non-repairable parts.

As mentioned before, spare parts are needed in maintenance of equipment. Kennedy et al. (2002, p. 202) state that maintenance can be divided into two types which are preventive maintenance and unplanned repair. In the case of preventive maintenance, the demand for spare parts can be predicted. In such maintenance, it can be possible to order parts just in time for the need. Conversely, in case of unplanned repair, the stock-out consequences can include remarkable costs. Thus some kind of safety stock policy is needed. Driessen et al. (2010, p. 4) have segmented types of maintenance as well. They have named preventive, corrective, and modificative maintenance. Preventive maintenance is done in order to prevent failures. This maintenance type is normally planned in advance and has to be performed within a predetermined time frame during which the equipment is in non-operating state. Delay in maintenance expands the non-operating time and thus decreases the operational availability of the equipment. Corrective maintenance refers to the overhaul that is conducted after a failure has occurred. This maintenance is usually unplanned due to unforeseen breakdown of a part. When a breakdown occurs, maintenance needs to be done immediately because also in this case, delay decreases the operational availability of the equipment. The third maintenance type, modificative maintenance, is done in order to improve performance of the equipment. This kind of maintenance can be delayed until all needed resources are available.

2.2. Special features of spare part business

Various companies have moved their focus from developing their manufacturing and product delivery processes to enhancing after sales services and customer support. The role of after sales business and spare part management is becoming increasingly vital and it has grown into a very profitable business area. Well-practiced service business can help to ensure stable, long-lasting cash flows and to establish firm customer relationships and customer loyalty. (Boone et al. 2008, p. 31; Legnani & Cavalieri 2010, p. 660.) Spare parts are vital for after sales business because they are needed to ensure efficient operation of main products and equipment, which makes spare part availability an important factor for companies. In a situation of machine break down, immediate availability of required spare parts can reduce the downtime substantially. Conversely, if spare parts are not available at once, the waiting time can cause major costs. The machined downtime can for instance result in lost revenues, customer claims and dissatisfaction, and public safety hazard. Because the capital machines are essential to the processes of the companies involved, machine downtime must be minimized. Machine downtime can be divided into two types which are the actual diagnosis and maintenance time and maintenance delay caused by unavailability of the needed resources. Hence a high level of spare part availability is important as it influences maintenance delay directly or indirectly. Direct influence refers to the case of corrective maintenance and indirect influence to the case of preventive maintenance. (Dekker & van Jaarsveld 2009, p. 575; Driessen et al. 2010, pp. 1-2.)

However, it is not obvious whether or not to keep various spare parts in stock. This dilemma arises from the fact that numerous items and high inventory levels cause high carrying costs. In spare part business, managers must analyze stocking decisions with available information such as price and lead time, usage, and shortage costs of the spare part. Thus the main objective of inventory management is to find the optimal balance between spare parts’ availability, tied capital, and operational costs. (Dekker & van Jaarsveld 2009, p. 575; Driessen et al. 2010, p. 3.)

Huiskonen (2001, pp. 125-126) writes that inventory management of spare parts is often perceived as a special case of general inventory management with some special features. In spare part logistics, effects of a stock-out can become extremely costly and thus the requirements for service are higher. On the other hand, the prices of individual parts can be remarkably high and demand of spare parts can fluctuate significantly, and thus the demand is difficult to forecast. Willemain et al. (2004, p. 375) state that intermittent demand, which refers to demand with a large number of zero values, makes accurate supply chain management of spare parts a difficult task. Typically, the demand is also lumpy which refers to the great variability among the non-zero values. Syntetos et al. (2011, p. 1) have defined intermittent demand as demand that appears at random, has periods with no demand at all, and is not necessarily a constant size. Intermittent demand is also known as lumpy, sporadic, or erratic demand and it is often associated with spare parts.

Also Gopalakrishnan and Banerji (2004, pp. 232-233) have determined special features of spare parts. According to them, the following characteristics distinguish spare parts business from others:

a) Demand is smaller and more uncertain
b) Manufacturing is uneconomical because of the uncertain and small demand
c) Excessive stock can be found in all levels of the supply chain
d) High tendency for item obsolescence
e) Large variety of items
f) Standardization and identification is difficult
g) A small percentage of different items account for large percentage of demand
h) Price has a large profit margin
i) Long lead time
j) Stock-out cost is larger than price of spare part
k) Failure data is difficult to get

Also Boone et al. (2008, pp. 34-36) have studied spare part business’ characteristics and they have determined top challenges of spare part business. Besides the previously described characteristics, they mention lack of holistic perspective, lack of system integration among different parties, and difficulty of planning the service requirements of ageing equipment. By lack of holistic perspective they mean that in spare part supply chain there are not enough collaborative relationships and the system is often viewed from the individual perspective. Lack of system integration refers to the fact that suppliers, service providers, and customers, have not established collaborative information systems. This leads to difficulty of satisfying customers’ needs because demand or part availability information is not completely transparent in the supply chain. Ageing products and parts cause challenges as well because many heavy types of equipment stay in service for decades after the end of production. Managing spare parts during the whole life cycle of maintained product presents a unique challenge to the managers.

2.3. Multi-echelon spare part system

In after sales services of large companies, it is normal to stock the same item in various locations. This is done because customers expect satisfactory spare part supply to the equipment and servicing company is usually willing to operate its spare part depots close to customers. In these situations service organizations usually have stocking points in various levels where higher level serves as a supplier to the lower level. This kind of system is known as multi-echelon spare part system. (Gopalakrishnan & Banerji 2004, p. 287.)

Figure 2.1 represents a simple example of multi-echelon inventory system. In the system, customer demand is fulfilled by inventories of branch warehouses which form the first echelon. On the contrary, branch warehouses' demand is fulfilled by replenishments from the central warehouse which is the second echelon. Central warehouse is replenished from outside suppliers. Inventory management of multi-echelon systems is complex task because demand of the branch warehouses is dependent on the demand of customers. And demand of the central warehouse is dependent on the demand and stocking choices of branch warehouses. (Silver et al. 1998, p. 475.)

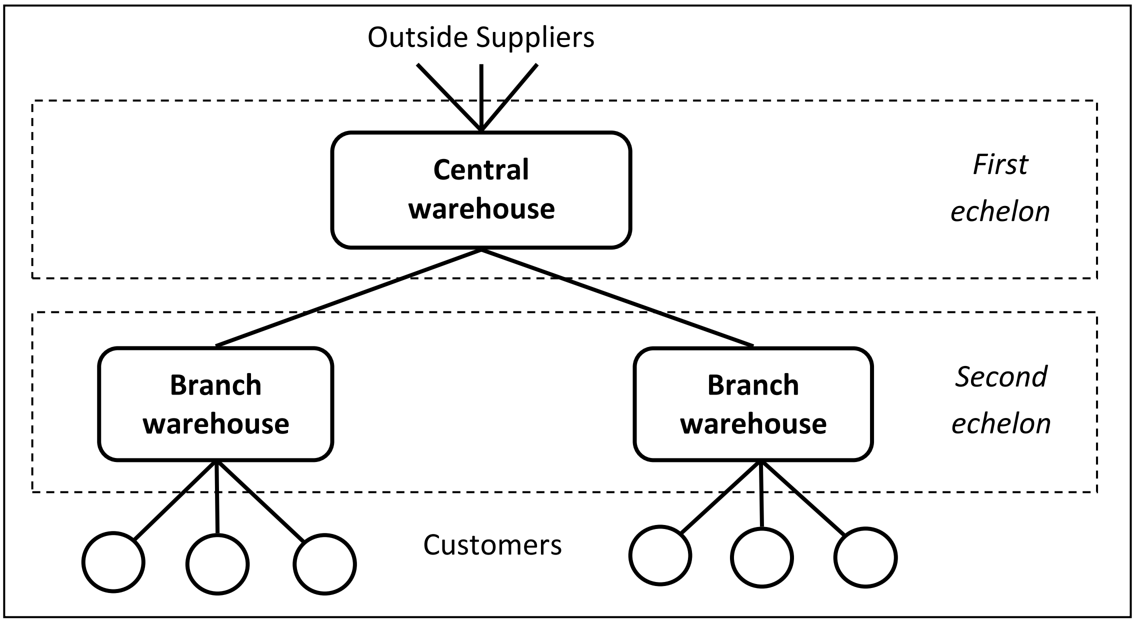

Figure 2.1. *An example of multi-echelon (two-echelon) inventory system (Adapted from Silver et al. 1998, p. 475).*

In multi-echelon inventory system, the focus should be on managing the whole supply chain rather than managing individual echelons (Paakki et al. 2011, p. 166). According to Stevenson (2007, pp. 503-504) supply chain can be defined as the string of organizations and their facilities, functions, and operations that are involved in producing and delivering products or services to end customers. The facilities can be for example factories, warehouses, distribution centers, or retail outlets. The functions and operations can include such as forecasting, purchasing, inventory management, and production. Supply chain management refers to the strategic coordination of business functions of an organization and its supply chain. The purpose of supply chain management is to integrate supply and demand management.

Successful firms do not generally try to adapt to various changes in their supply chain but try to change it themselves. If the firm does not try to control supply and demand variability proactively, the variability will be taken as given, and inventory management has to adjust passively to the environment's restrictions. In this kind of situation, the successfulness of inventory management is determined by other parties of the supply chain. This usually leads to sub-optimization in the supply chain where each single stocking echelon or chain member uses reactive methods and optimizes their own operation. Thus the firm can only control one aspect which is the variability in internal processes. The three aspects of inventory management, supply, demand, and internal process, are represented in figure 2.2. As the figure shows, in case of reactive management demand and supply variability are not in control, and this causes sub-optimization of own processes. This can actually decrease the performance of the whole chain. Hence, role of supply chain management should be stressed and efforts should be made also to reduce demand and supply variability in the chain. (Paakki et al. 2011, p. 166.)

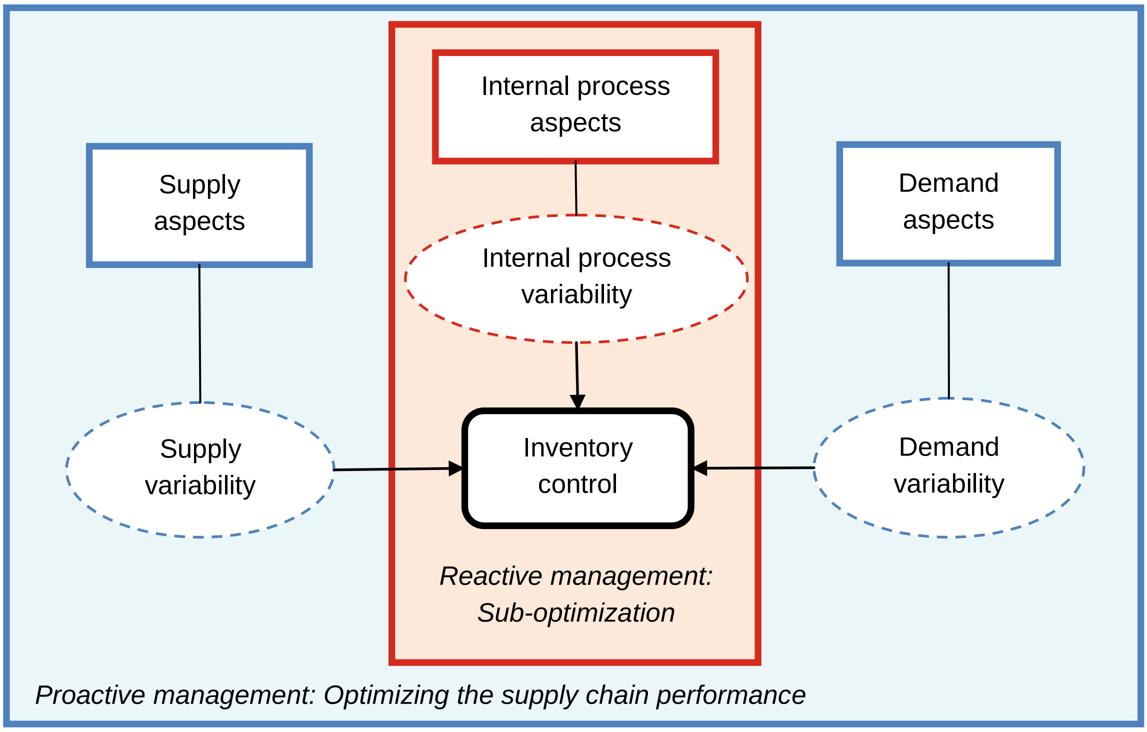

Figure 2.2. *Three aspects of inventory management (Adapted from Paakki et al. 2011, p. 166).*

In case of spare part supply chains, the control is typically focused on individual inventories and not on the chain as a whole. In order to form an efficient inter-company supply chain, open information sharing and collaboration must exist in the chain. (Huiskonen 2001, p. 126). There are many disadvantages in multi-echelon operations where every echelon makes their independent replenishment decisions and demand information is not transparent. First of all, the customer is dependent on the sufficiency of branch warehouse's stock. If branch warehouse has a stock-out, the lead time can be as long as the branch warehouse's order lead time plus transportation time to customer. Secondly, it ignores the cost consequences at one echelon of applying particular ordering logic in another echelon. The third point is that it causes the bullwhip effect to the supply chain. This refers to the phenomenon where the orders placed by customer become progressively larger, more fluctuated, and less frequent when moving upstream in the chain. (Silver et al. 1998, p. 487.)

3. SPARE PART INVENTORY MANAGEMENT

3.1. Basic questions of inventory management

The purpose of inventory management is to control inventory levels, inventory positioning, and related matters within an organization. The importance of inventory management has long been evident for companies. However, inventory control is still a difficult task in many supply chains which have complex structure. (Simchi-Levi et al. 2004, p. 89; Waters 2009, p. 338) One of the main questions of inventory management is how to efficiently control stock while ensuring availability of parts. Holding parts in stock ties company's capital and resources which can restrict sales growth. Furthermore, the value of stocked technical parts usually declines in the course of time. Thus high inventory levels can be seen as a financial burden. (Happonen 2011, p. 1).

Inventory management consists of many sub-dilemmas. For example, companies must determine which items are most important for the operation and how they should allocate control resources. They should also determine what items should be stocked, when orders should be placed, and how much should be ordered. In addition, companies should measure customer service and item movement, and analyze costs of inventory. (Waters 2009, pp. 335- 338.)

3.2. Inventory costs

Managing spare parts is an important task also because of the enormous cost implications for the organizations holding inventories (Syntetos et al. 2008, p. 292). There are three basic costs which are associated with inventories. These are carrying cost, ordering cost, and shortage cost. Carrying cost refers to the costs of holding an item in stock; ordering cost refers to the costs of ordering and receiving inventory; and shortage cost occurs when demand cannot be fulfilled from the inventory. (Stevenson 2007, pp. 547-548.) Details of these three inventory costs are described next.

3.2.1. Carrying cost

Inventory carrying cost is the expense associated with carrying an item in inventory for a certain length of time such as a year. These costs include interest for the invested capital, insurance, taxes, depreciation, obsolescence, deterioration, spoilage, breakage, and warehousing costs such as heat, light, and rent. Carrying costs can be presented in two different ways. One way is a percentage of a unit price and the other is monetary amount per item. Total inventory expense can be calculated by multiplying average inventory level by annual inventory carrying cost rate. When doing so, a standard accounting procedure is to use purchase costs rather than selling prices. (Buker 2001, pp. 1090-1091; Bowersox et al. 2002, p. 289; Stevenson 2007, p. 547.)

Stevenson (2007, p. 548) states that annual carrying cost varies typically between 20 and 40 percent of the item value but the exact carrying cost used by a company is determined by inventory management policy. Waters (2009, p. 341) writes that average annual carrying cost of stock used by companies is around 25 percent of the value. Inventory carrying cost consists of the costs presented in table 3.1. The percentages in the table are only guidelines since the costs can vary widely between companies.

Table 3.1. *Components of inventory carrying cost (Waters 2009, p. 342).*

Component	Percentage of unit cost per year
Cost of capital	8-15
Storage space	2-5
Loss and obsolescence	4-6
Handling	1-2
Administration	1-2
Insurance	1-5
Total	**17-35**

Silver et al. (1998, p. 45) define that inventory carrying cost consists of the opportunity cost of the capital invested, costs of warehouse operating and special storage requirements, handling and counting costs, deterioration, damage, theft, obsolescence, taxes, and insurance. The most common calculation method for inventory carrying cost is:

$$C_y = \bar{I}vr$$

where

C_y = Carrying costs per year
$\bar{I}$ = Average inventory in units
v = Unit value (purchasing price)
r = Carrying charge

In previous formula, $\bar{I}v$ is the average inventory in euros. The third variable is carrying charge, r, which refers to the annual cost of carrying one euro of inventory. The largest percentage of the carrying charge comes from opportunity costs of the invested capital. This means that otherwise the invested capital could be used elsewhere in the company and this opportunity is lost because of capital tied in the inventory. The opportunity cost is not measured by traditional accounting systems but it can be defined easily enough. Basically, because of the investment in inventories, the capital cannot be invested on the next most attractive opportunity and the return on that possible investment is lost. But the next most attractive investment can differ from day to day and in practice, this kind of factor is difficult to manage. The value of *r* should also depend on the degree of investment risk and cost of storage which depends on bulkiness, weight, handling requirements, insurance, and possible taxes. All these factors should be analyzed for each stock-keeping unit (SKU) and thus the value of *r* should be different for every SKU. But to make inventory management less difficult both from theoretical and practical point of view, a fixed value of *r* is usually given for the majority of SKUs. (Silver et al. 1998, pp. 45-46.)

3.2.2. Ordering cost

Ordering and order processing involve various activities which cost money (Gopalakrishnan and Banerji 2004, p. 235). According to Stevenson (2007, p. 548) ordering cost refers to the cost of ordering and receiving inventory. Accordingly, ordering cost differs from the purchasing cost which means the cost of goods (COGS). Ordering costs vary with the amount of placed orders because the ordering costs are typically expressed as a fixed monetary amount per order. Thus the size of the order does not effect on the cost per order. Ordering costs include shipping, preparing invoices, inspecting of goods upon receiving, and other handling costs.

Silver et al. (1998, pp. 46-47) define ordering cost as the fixed cost associated with a replenishment. It is independent of the size of the order and is composed of order forms, typing of orders, freight cost, receiving and inspection, handling of invoices, and following up on unexpected situations. Several of these components can be quite difficult to determine if one wants to define a precise value for ordering cost. Often it is more beneficial to change the underlying procedures which determine the cost, rather than spend time on calculating the ordering cost.

3.2.3. Shortage cost

Shortage cost occurs when demand for an item exceeds the supply of inventory (Stevenson 2007, p. 548). Waters (2009, p. 342) writes that the most obvious cost of shortage is the opportunity cost of not making a sale. This refers to the profit that is lost because of inventory shortage. However, the consequences of shortage are usually much greater. Shortages can decrease company’s goodwill, deteriorate reputation and image, eliminate potential future sales, and cause penalties.

Shortages often result in back-orders. In a back-order situation, the customer will have to wait for their order to be filled. Thus the sale is not lost but delayed. Back-orders usually generate additional administrative and sales costs. (Ballou 1999, p. 319.) In addition, extra logistical costs may arise when orders cannot be delivered through normal distribution chain. The special arrangements include expenses caused by remedial actions. These are actions such as expediting replacement orders, making emergency orders, paying for special deliveries, and utilizing more expensive suppliers. (Waters 2009, p. 342)

Waters (2009, p. 342) states also that it can be challenging to get reliable figures for any of these inventory costs. However, he mentions that it is particularly difficult in case of shortage costs. Shortages include so many intangible factors that it is challenging to determine a reasonable value for the cost. A good rule-of-thumb is that shortages are expensive, so in general it is reasonable to avoid them. This means that companies are more willing to pay the relatively lower costs of carrying inventory in order to avoid the relatively greater costs of stock-outs. Unfortunately, this kind of approach tends to grow inventory levels especially in case of uncertain demand.

3.3. Inventory replenishment

Inventory replenishment is essential aspect in inventory planning. Key questions of replenishing include how often inventory status should be determined and when items should be ordered? Other issue that requires consideration is how many pieces should be ordered? These questions are much related to each other. In addition, it is important to determine methods of measuring the performance of inventory management. Before we can answer these questions, different stock types must be defined.

3.3.1. Stock types

Safety stock method is commonly practiced in inventory management when planning against uncertainty (Kanet et al. 2009, p. 6859). Safety stock can be defined as the proportion of stock which is maintained in order to protect against demand and performance uncertainty. Thus it is the average level of stock at the time when new replenishment arrives. Hence this part of the stock is used merely at the end of the replenishment cycle when for some reason, the demand is higher than expected or replenishment cycle has taken more time than expected. (Silver et al. 1998, p. 31; Bowersox et al. 2002, p. 287.) In other words, safety stock is the additional inventory which is carried in order to decrease the risk of stock-out during lead time. Order lead time is the time between placing and receiving the order. The amount of safety stock is determined by uncertainty that exists. The uncertainty can be caused for example by variance in lead time and lead time demand. In addition, errors in inventory levels and received lot sizes cause uncertainty, and the third factor is the desired service level. (Hoppe 2006, p. 257; Stevenson 2007, pp. 564-565.)

Necessary safety stock can be determined by using historical demand data and probability calculus. The probability of specified events forms into a distribution pattern around the average value of all occurrences. The most basic distribution used in inventory management is the normal distribution which is a symmetrical bell shaped curve where the mean value is at the center point. A certain distance from the mean value represents a certain probability of occurrence realization in this area. (Silver 1998, p. 122; Bowersox et al. 2002, p. 300.) This is illustrated in figure 3.1.

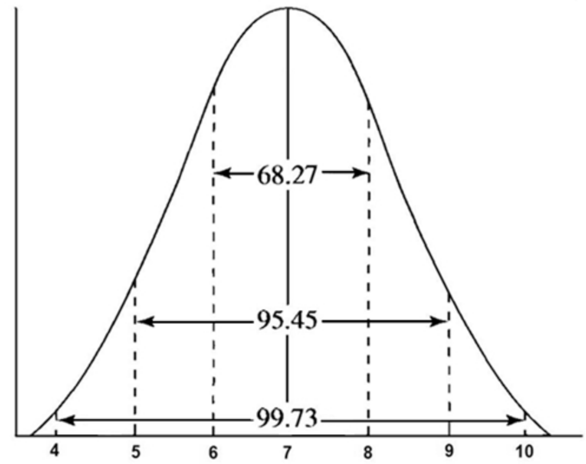

Figure 3.1. *Example of normal distribution (Adapted from Bowersox et al. 2002, p. 300).*

Bowersox et al. (2002, pp. 300-301) write that standard deviation is the basis of using normal distribution when forecasting demand during order lead time. Standard deviation represents the dispersion of occurrences within specified areas of the normal curve. Thus the higher standard the deviation is, the more widespread the normal distribution curve gets. Calculating the standard deviation is the first step when determining safety stocks. Standard deviation can be computed with spreadsheets but it can also be calculated manually with the following formula:

$$\sigma = \sqrt{\frac{\Sigma F_i D_i^{2}}{n}}$$

where

σ = Standard deviation
F_i = Frequency of event i
D_i = Deviation of event from mean value of event i
n = Total number of observations available.

According to Bowersox et al. (2002, s. 306) and Silver et al. (1998, p. 259), the calculated standard deviation is then used in the formula of safety stock. Required safety stock can be calculated as follows:

$$SS = k\,\sigma_{dLT}$$

where

SS = Safety stock in units
k = Safety factor
σ_{dLT} = Standard deviation of lead time demand

Safety factor k determines the probability of a stock-out. It depends on the stock-out risk that the company is willing to accept. General rule is that the smaller the accepted risk, the greater the safety factor. Factor k can be determined by spreadsheet or the table in appendix 1 after the service level is decided. Figure 3.2 represents the connection between determined service level, stock-out probability, and safety factor. (Bowersox 1998, p. 306; Stevenson 2007, p. 565.)

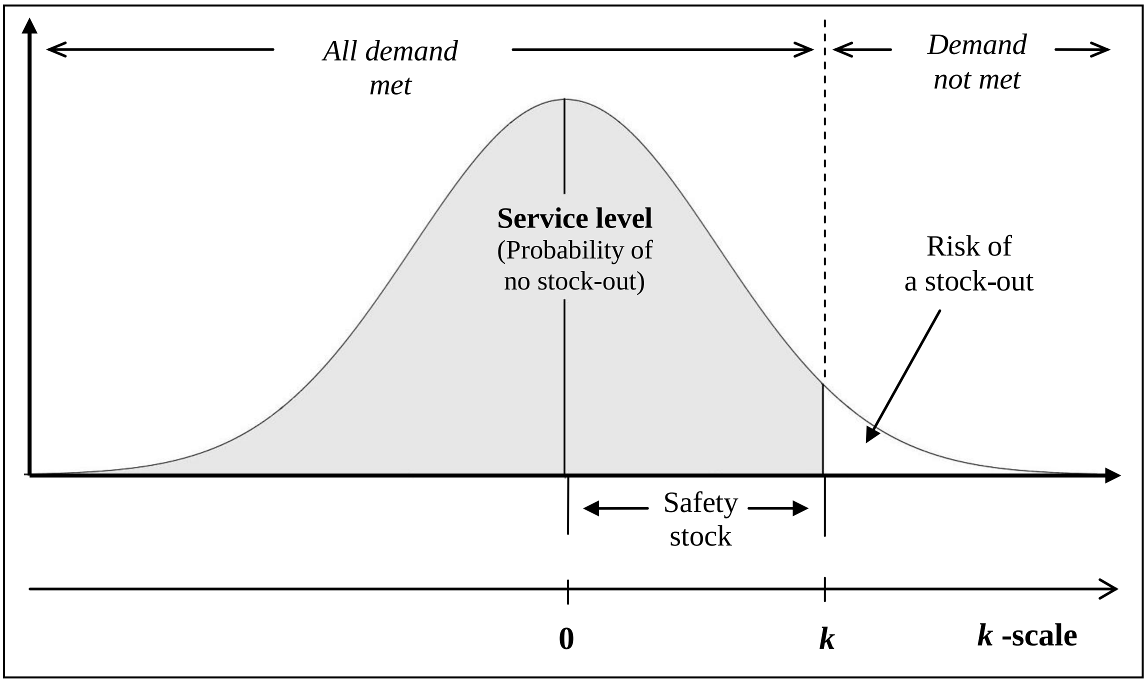

Figure 3.2. *Connection between service level, probability of stock-out, and safety factor (Adapted from Stevenson 2007, p. 565; Waters 2009, p. 356).*

Traditionally, the required safety stock is computed by first estimating the risk and then setting the safety stock amount to a certain appropriate level. This level is then maintained for the entire planning horizon. This traditional way is quite constricted because it is calculated under assumptions such as stationary and normally distributed demand forecast error. It is also assumed that replenishment lead time is static. However, there are also new and more advanced methods which allow dynamic updating of the value when the conditions alter. In these methods, calculations are done by system that uses dynamic updating and thus provides varying safety stock targets. This kind of method is sensible in situations where lead time demand is not stationary, for instance when part's lead time or demand is not constant. It is shown that in these cases, inventory savings are remarkable if constant safety stock policy is replaced with dynamically planned safety stock. (Kanet et al. 2009, pp. 6859-6860.)

Companies typically purchase parts in order cycles and in quantities that exceed their immediate demand. Because of this, companies need to store some or the entire ordered amount for later use. This part of the stock is known as cycle stock. (Stevenson 2007, p. 543.) Murphy & Wood (2008, p. 218) define cycle stock as the inventory that is needed to satisfy expected demand during the order cycle. Thus cycle stock is the amount of ordered quantity of one order cycle.

Another inventory management related stock concept is average stock. Bowersox et al. (2002, p. 287) define it as a combination of safety stock and cycle stock. It is the sum of safety stock and half of the cycle stock. Thus average stock can be decreased by lowering level of safety stock or ordered quantity. The three above mentioned stock types are presented in figure 3.3.

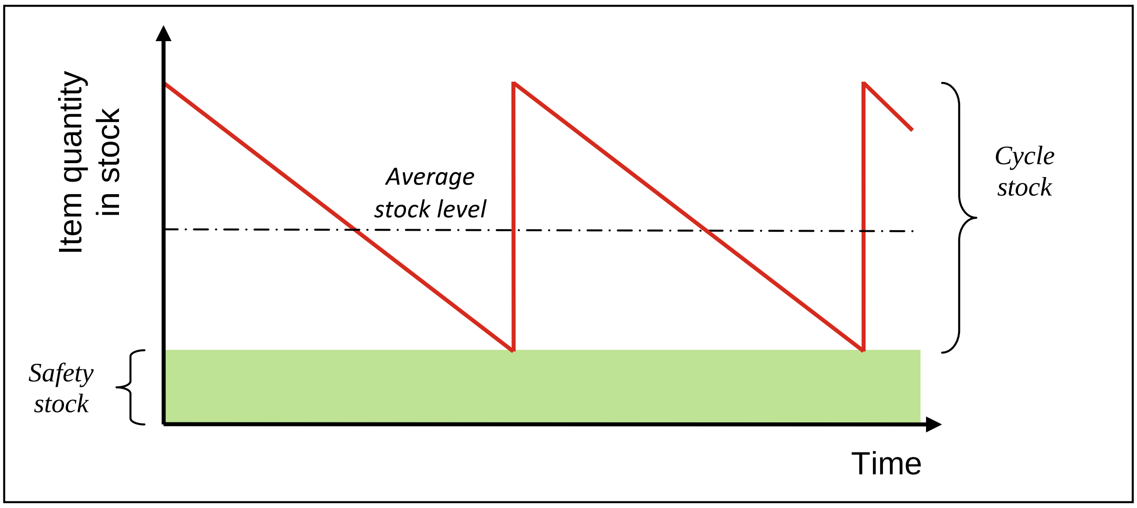

Figure 3.3. *Safety, average, and cycle stocks.*

In addition, Ballou (1999, p. 312) adds one more stock type which is called obsolete, dead, or shrinkage stock. This refers to stock which has deteriorated or become out of date in the course of time. It includes also stock which has been lost or stolen. This type of stock is particularly relevant with high value products. Van Jaarsveld and Dekker (2011, pp. 423-424) define spare part obsolescence or dead stock as stocked parts that are no longer used. These non-moving parts correspond to significant share of the inventory value. Although these parts are not used, they still tie up capital and increase inventory carrying costs, without influencing to the overall service level. Typically in cases, where there is no longer demand for the parts, the only method to get rid of the stock is scrapping the parts. Hence dead stocks can be costly regardless of how they are handled. And because of this fact, preventing or at least controlling the emergence of dead stocks is important in order to keep expenses down.

Van Jaarsveld and Dekker (2011, p. 424) describe that build-up of dead stock results mainly from decreasing demand. When a part is demanded during the forecast period, stocking of the part is triggered. But when the forecasted demand does not occur and as a matter of fact, there is no demand even during following years, the stock of part in question turns into dead stock. After these years, the stock either begins to move again, or it remains dead. Thus the period without demand can result from temporary demand variation or from permanent demand decrease. Compared to the latter case, the costs are much lower in the former case.

Temporary demand variations can be caused by various reasons. They typically originate from fluctuation in the time between equipment refurbishments and diverse wear and tear patterns of individual parts. Variations in the number of accidents and incidents can cause temporary demand deviation as well. Conversely, permanent demand decrease of a spare part can result from changes in maintenance policy or operating conditions of original product, and also from new part replacements. The maintenance policy affects significantly part consumption rates. If equipment downtime costs decrease, less effort will be put on the maintenance, and this decreases the consumption rates. The effect of operational changes is also relevant. The spare part consumption rates can vary if equipment's operating conditions or locations are changed. However, in these cases it is difficult to predict how exactly the consumption changes. Thirdly, alternative parts can be an important cause of obsolescence. The demand decrease is especially difficult to predict in cases where customer changes to alternative spare part sources. Most complex equipment manufacturers have large supplier base which is why customers can sometimes bypass the manufacturer's spare part service and purchase parts directly from suppliers. (Van Jaarsveld & Dekker 2011, pp. 424-425.)

3.3.2. Reorder quantity

Order quantity determines how much is ordered in one order cycle. The greater the order quantity, the larger the average inventory and thus, the larger the inventory carrying cost. But on the other hand, when the order quantity is increased, fewer orders are needed per period and hence the total ordering cost is lower. The purpose of order quantity sizing is to find economic balance between these two aspects. One replenishment principle is the economic order quantity (EOQ) which minimizes the combined cost of inventory carrying and ordering for one item. (Bowersox et al. 2002, p. 292.)

Principle of EOQ can be seen from figure 3.4 which includes graphs of carrying costs, ordering costs, and total cost. The optimum point is at the point where total cost is lowest and that is at the intersection of the first two graphs. When identifying the EOQ, it is assumed that demand and costs are comparatively steady throughout the year, and variable cost of unit does not depend on the order quantity. It is also assumed that there are no shortages and the entire quantity is delivered at once, the planning horizon is very long, and there are no minimum or maximum order sizes. This kind of simplified situation is a sensible estimation of reality in particular cases. (Silver et al. 1998, pp. 149-150; Murphy & Wood 2008, p. 224.)

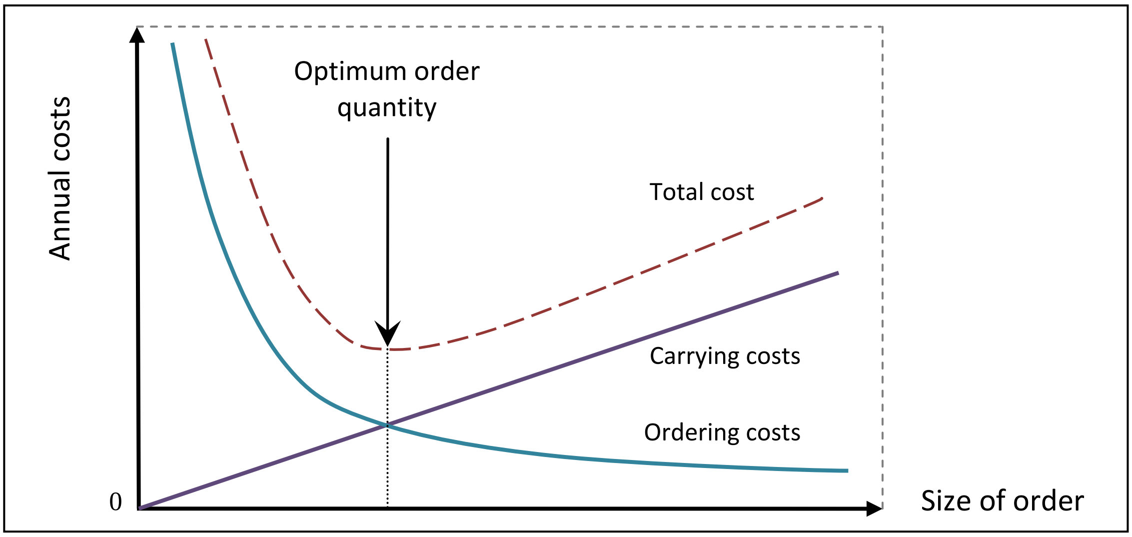

Figure 3.4. *Determining EOQ with graph (Adapted from Murphy & Wood 2008, p. 223).*

According to Silver et al. (1998, pp. 152-154), the lowest point of total cost curve is the EOQ. This is the point where the slope of the curve is zero. The EOQ can be computed with following formula:

$$\mathrm{EOQ} = \sqrt{\frac{2D_yA}{vr}}$$

where

D_y = Demand per year
A = Fixed cost component for each replenishment (€)
v = Unit value (purchasing price)
r = Carrying charge

This formula is also called as the Wilson lot size. It is one of the earliest and most common results of inventory management theory. EOQ's formula and figure demonstrate that large and infrequent orders lead to high carrying cost and low ordering cost. Conversely, small and frequent orders lead to low carrying cost and high ordering cost. (Waters 2009, p. 346.)

A common problem of EOQ is that it can give impractical order quantity. For example, it might suggest to order 86,6 pieces. This could be rounded to 87 pieces but purchaser might prefer to order 90 or even 100 pieces. The question is how much the rounding would effect on overall costs? The total cost curve is always gradual around the EOQ-point, and thus the costs rise slowly. If purchaser orders between 64 percent and 156 percent of the EOQ, the variable costs will still be within 10 percent of the minimum. And if purchaser orders between 54 percent and 186 percent of the EOQ, the variable costs will be within 20 percent of the minimum. Thus EOQ is a good guideline in many different situations and this is also one reason why it is so widely used method. (Waters 2009, p. 350.)

Advantages of EOQ-model include the fact that it is easy to understand and that it is widely used. Thus the model is well-known and accepted by most companies. It is also easy to implement and extend, it gives good guidelines for order size, and it gives also other values such as costs and cycle periods. However, EOQ-model has also various weaknesses. For instance, it takes a quite simplified view of inventory systems. These simplifications include presumptions that demand is known and constant, all costs are fixed, lead time is constant, and there is no uncertainty in supplies. In addition, EOQ-model is not the most optimal method for situations where demand is highly sporadic. In these situations it can produce distorted control information. (Waters 2009, p. 353; Happonen 2011, p. 23.)

3.3.3. Continuous review policy

In continuous review policy, also known as continuous replenishment system, the inventory is reviewed continuously and purchase decisions are subjected to the item quantity on hand. The policy is based on reorder point (ROP) which is the predetermined point of item quantity in stock which triggers a purchase impulse. In other words, when the stock level drops to this amount or below it, a new order for the item will be placed. (Silver 1998, p. 237; Simchi-Levi 2004, p. 92.) Principle of reorder point is illustrated in figure 3.5.

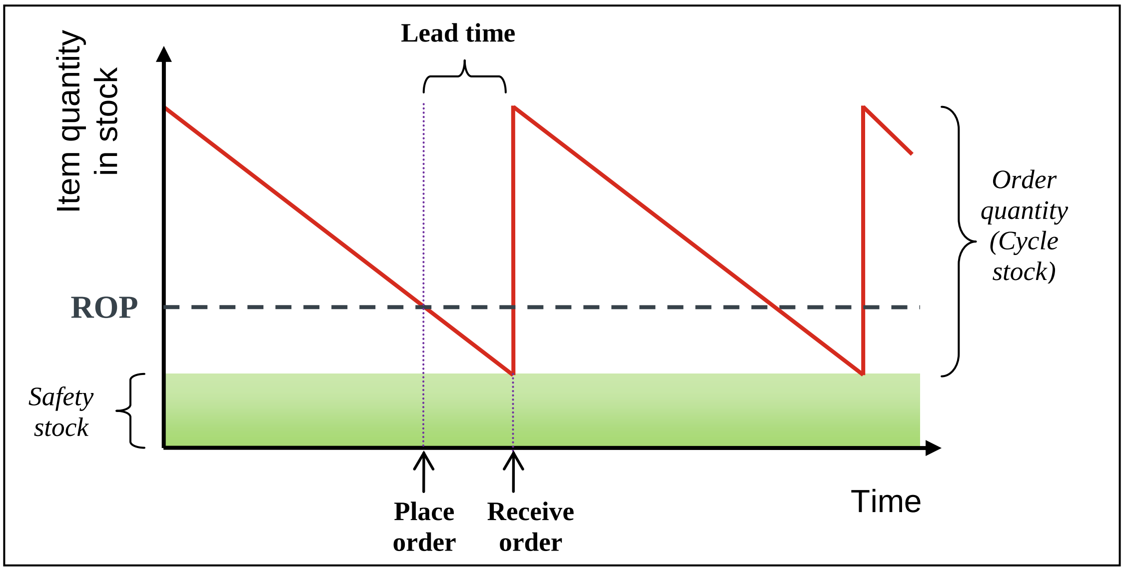

Figure 3.5. *Continuous review policy and related terminology (Adapted from Stevenson 2007, p. 571).*

Reorder point quantity is determined by four factors which are the rate of demand, the order lead time, the variability expanse of the previous two, and predetermined service level. Reorder point can be determined by a function of the average demand during expected lead time and the required safety stock. (Stevenson 2007, p. 563; Ruiz-Torres & Mahmoodi 2010, p. 2842.) According to Bowersox et al. (2002, p. 291), reorder point can be calculated by multiplying average daily demand in units with average order lead time in days. But because uncertainty exists usually in either demand or lead times, safety stock needs to be taken into account. The formula for reorder point with uncertainty is:

$$\mathrm{ROP} = \mathrm{D_d} \times \mathrm{LT} + SS$$

where

D_d = Average daily demand in units
LT = Average order lead time in days
SS = Safety stock in units

3.3.4. Periodic review policy

In periodic review policy, also known as replenishment cycle system, the inventory is reviewed at regular intervals and the required quantity is ordered after each review. For instance, regular interval can be once a week or once a month. One way is to calculate EOQ and find the period in which the orders are approximately this size. The periodic review is used widely by companies and the specific way of using depends on management judgement. (Simchi-Levi 2004, pp. 93-94; Waters 2009, p. 360.) A typical behavior of periodic review system is illustrated in figure 3.6.

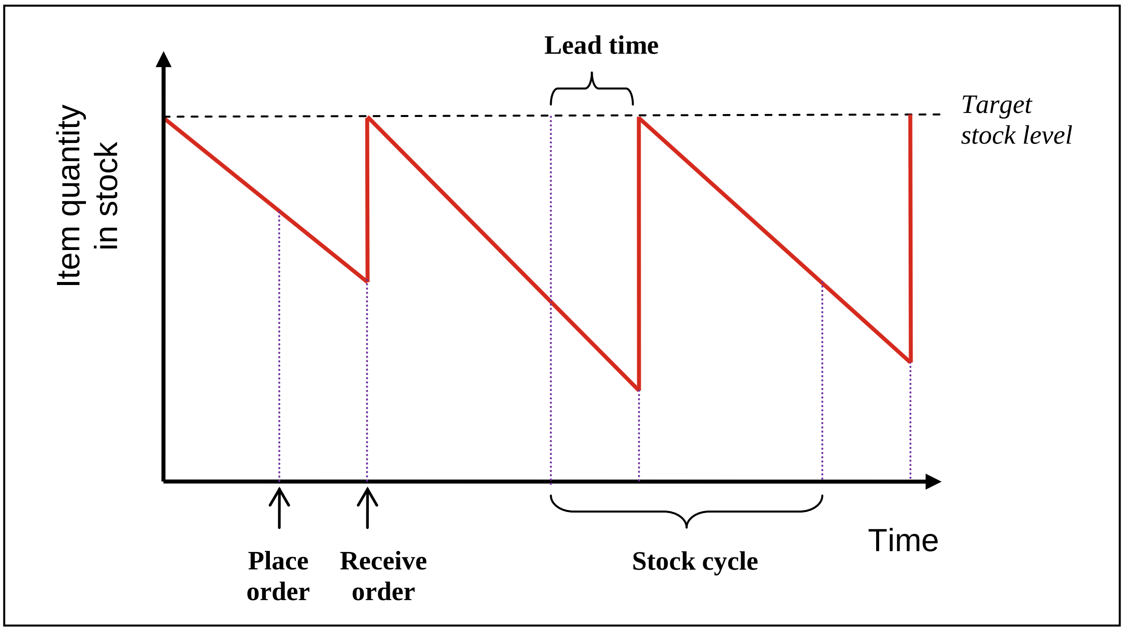

Figure 3.6. *Periodic review policy (Adapted from Waters 2009, p. 360).*

Waters (2009, pp. 360-361) states that target stock level, which is shown in previous figure, is important factor in periodic ordering. The system works by reviewing the stock on hand at predetermined intervals and ordering an amount that brings the stock amount to the target level. The target stock level is determined by the amount of safety stock and by the demand during stock cycle and lead time. The appropriate target can be calculated as follows:

$$S_T = D_T + D_{LT} + SS$$

where

S_T = Target stock level
D_T = Mean demand during stock cycle
D_{LT} = Mean demand during lead time
SS = Safety stock in units

According to Waters (2009, p. 360), when the target stock level is known it is a straightforward task to determine suitable order quantity. At the periodic order point, the required order quantity can be calculated as follows:

$$Order\ quantity = S_T - S_H$$

where

S_T = Target stock level
S_H = Stock on hand

The periodic review policy has both advantages and disadvantages. Advantages include for example the fact that order grouping is possible if multiple items are ordered from same location. This can reduce clerical work and ordering costs. Order grouping brings savings in purchasing of high demand items because inspection and transportation expences are relatively lower. However, these savings are not accessible with low demand items because the economies of scale is not achieved. The periodic review system causes also higher safety stocks which increases inventory carrying costs. (Axsäter 2006, p. 47; Stevenson 2007, p. 573.)

Silver et al. (1999, pp. 240-241) state also that it is possible to combine periodic and continuous review policies. In this case, the basic idea is to use periodic review with predetermined ROP. Thus inventory is reviewed at stock cycle intervals and if the inventory level is at ROP or below it, then company orders enough to raise inventory level to target level. If the inventory level is above ROP at the review point, nothing is done until at least the next review point.

3.4. Item classification

Companies might need thousands of different items in their business. Stocked items can differ strongly in terms of stock-out effects, value, and demand. In circumstances like this, it is not be reasonable or even possible to manage all of the items equally because it would demand too much time and effort. Thus items are usually classified in different categories so that companies can focus on managing the most important ones. (Sakki 1999, p. 100; Molenaers et al. 2011, p. 1.) Stevenson (2007, p. 548) describes that different items are not identical in terms of profit potential, sales volume, money invested, or late delivery penalties. Thus it is advisable to allocate inventory management efforts based on these item characteristics and relative importance of the item.

3.4.1. ABC-analysis

ABC-analysis is a well-known classification tool which is based on Pareto principle. This principle refers to noted statistical regularity in the usage rates of different items. Common situation in inventories is that approximately 20 percent of different items are accountable for 80 percent of the total annual monetary usage. Respectively, the rest 80 percent of items account for 20 percent of the monetary usage. For inventory management perspective, the focus should be on the first 20 percent of items that generate the 80 percent of the annual monetary usage. Figure 3.7 represents this distribution by value. (Silver et al. 1998, pp. 32-33; Ng 2007, p. 344; Murphy & Wood 2008, p. 227.)

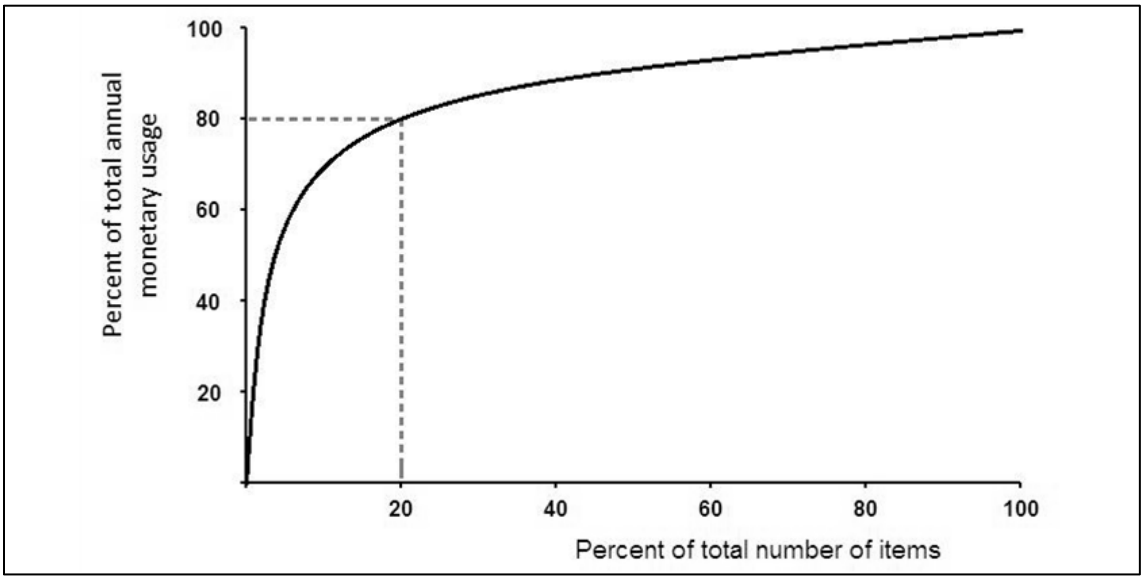

Figure 3.7. *Distribution by value of items (Adapted from Silver et al. 1998, p. 33).*

Bowersox et al. (2002, pp. 323) state that ABC-classification helps management to establish specific inventory strategies for specific item groups which have different level of importance. For example, items with high monetary usage are typically targeted for higher service level which naturally requires different inventory management procedures and relatively higher level of safety stock. Respectively, in order to decrease inventory levels, items with lower usage may be allowed lower service levels and thus less safety stock. Waters (2009, p. 362) categorizes different classes and corresponding importance levels so that A-class includes expensive items which need special care, B-class includes ordinary items which need standard care, and C-class includes items needing only little care.

In ABC-analysis, the class A usually accounts for 10-20 percent of the number of items and 60-70 percent of annual monetary usage. Respectively, class C items account for 50-60 percent of the number of items and only 10-15 percent of the annual monetary usage. Class B items stand between these two classes. This distribution varies in different companies but the common principle exists in most cases; relatively small number of items generate large share of the annual monetary usage. In terms of importance, A-class items should be the ones with highest focus and C-class items with the lowest focus. (Stevenson 2007, pp. 548-549; Murphy & Wood 2008, p. 227.) Silver et al. (1999, p. 100) suggest a classification method which divides items into three classes where A-class covers the first 80 percent of the monetary usage. Conversely, B-class covers the next 15 percent and C-class the last 5 percent.

In many cases ABC-analysis includes also fourth category, D, which includes items with very low monetary usage or with no usage at all. Items in this class can also cause negative effects to the business if keeping these parts cause high costs and low income. (Murphy & Wood 2008, p. 228.) The method can easily be expanded to even more classes by dividing the ranked SKUs into more classes. However, the amount of classes is usually limited to six at most. (Syntetos et al. 2008, p. 294; Teunter et al. 2010, p. 344.)

3.4.2. Classification by demand pattern

ABC-analysis is based only on single measurement, annual monetary usage, which makes the classification tool quite simple and constricted. It is important that this one measurement is not the only way to classify items. Multi-criteria classification tools have been developed during past two decades. (Ng 2007, p. 345; Teunter et al 2010, pp. 344-345.) According to Sakki (1999, pp. 105-106) and Hoppe (2006, p. 53), one possible supplementary classification method is XYZ-analysis. It is a classic secondary analysis which is basically a modification from ABC analysis. These classifications are done in similar way but in XYZ-analysis the item classification criterion is the consumption pattern of each item. The classification criterion can be for example the number of sales transactions over a predetermined time period. Items are then assigned to different classes depending on how regularly they are sold. XYZ-analysis provides valuable information about items because logistic costs are usually correlated to the number of transactions.

Items in different XYZ-classes have different characteristics. X-items are characterized by a constant and smooth usage over time. The demand fluctuates relatively slightly around a constant level which means that in principle, the future demand can be forecast rather well compared to other classes. However, forecast errors do happen also with X-items. The second group is Y-items which have neither constant nor sporadic usage pattern. This means that for these items, it is more difficult to obtain accurate forecasts. Nonetheless, it is possible to observe trends, such as momentary increases, decreases or seasonal trends in the usage. The third group, Z-items, is the most difficult one in terms of forecasting because these items are not used regularly. The usage can fluctuate significantly or be completely sporadic over time. In these cases, items can often have periods with no usage at all. It can be useful to subdivide the Z-segment into Z1- and Z2-segments, the latter being consumed even less constantly than the former. (Hoppe 2006, p. 60.)

Results of XYZ-analysis can also be combined with results of ABC-analysis. These two tools support each other and the result will be more extensive analysis than what only one measurement provides. ABC-analysis is usually done first and then the items in each category are classified also based on the number of transactions. An example of combined ABC-XYZ -analysis is illustrated in figure 3.8. Especially inventory of items in category C/X should be re-considered because these items do not bring much revenue but they cause high processing costs. (Sakki 1999, pp. 105-106.)

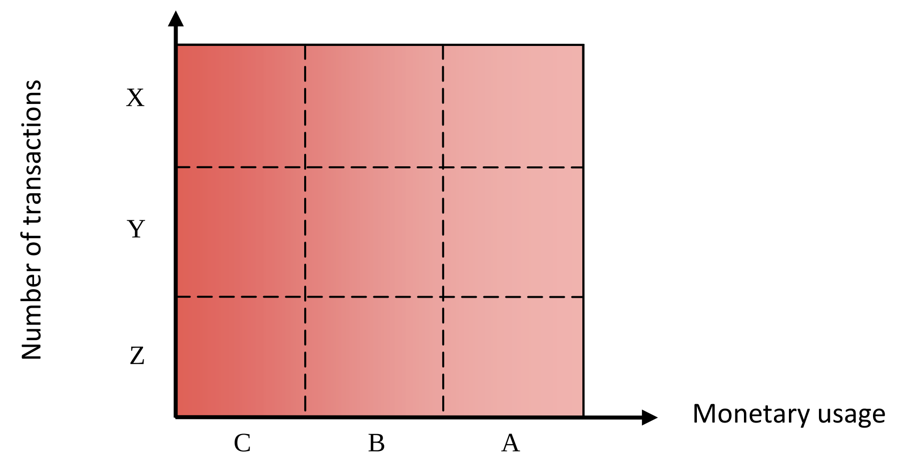

Figure 3.8. *ABC-XYZ –classification matrix (Adapted from Sakki 1999, p. 106).*

Happonen (2011, p. 119) has studied inventory classification by demand pattern. He has chosen two classification factors which are demand transaction frequency and variety of individual demands' size. These factors were chosen because they are easy to measure and well understood in practice. When these two parameters are combined, four demand pattern segments are formed. The segments are sporadic demand, spiky demand, smooth demand, and slowly and seasonally moving items. The classification is illustrated in figure 3.9.

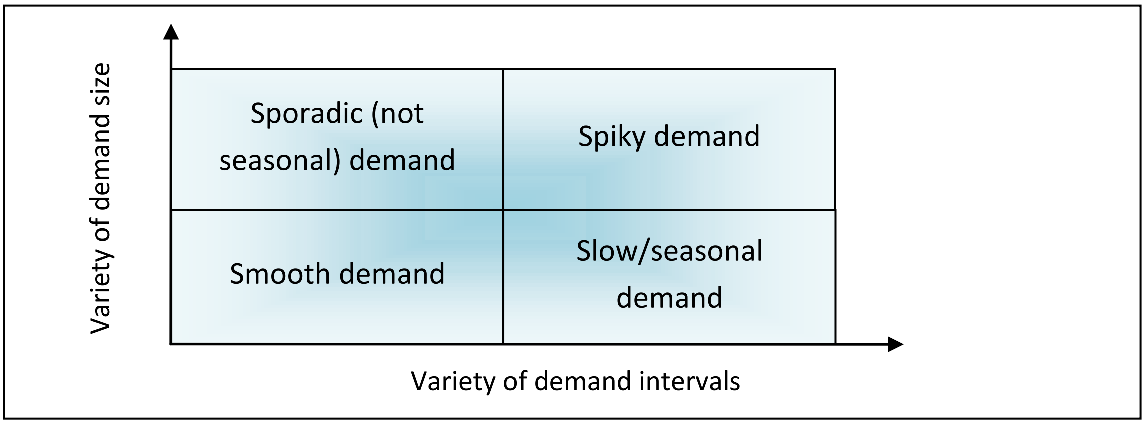

Figure 3.9. *Classification by demand pattern (Adapted from Happonen 2011, p. 119).*

Also Eaves and Kingsman (2004, p. 432) have created a demand pattern classification tool. They have divided inventory into five segments by demand pattern of items. Demand pattern classes are smooth, irregular, slow moving, mildly intermittent, and highly intermittent. The criteria behind segmentation are transaction variability, demand size variability, and lead time variability. Each of the variabilities is divided into low and high classes, and combination of these determines in which class an item belongs. The boundaries between low and high should be decided by managers.

3.4.3. Other classification possibilities

One problem is that an item can have a low annual monetary usage or transaction amount but still be important for customers. Thus it should be possible to categorize items in A-class simply because they are crucial for company's operation. It is advisable to use at least two measurements or criteria when classifying inventory items. Classification systems can also be based on multiple criteria. Possibilities for classification criteria are for example inventory cost, part criticality, lead time, scarcity, stock-out penalty, and order size requirement. (Silver et al. 1998, p. 35; Bowersox et al. 2002, pp. 323-324; Ng 2007, p. 345.)

Suitable categorization is a necessary management method when investigating stocking policies such as which items should be kept in stock. Adapting single ordering policy for the entire inventory assortment is not reasonable because too many compromises must be made in adjusting the control parameters. The diversity of spare part management characteristics has induced many possible criteria for the item categorization. However, the appropriate criteria depend on the actual situation and thus not all of them are relevant. It is reasonable to design situation-specific approach with a subset of the criteria. (Fortuin & Martin 1999, p. 959.) Heinecke et al. (2011, p. 2) describe that there are two fundamental issues that need to be taken into account when designing a classification model. First of all, managers must decide which criteria or parameters are used for classification purposes. And the second issue is how many classes there should be and how suitable cut-off values are decided.

Molenaers et al. (2011, p. 1, 4) describe that the concept of important item differ in after sales business compared to traditional inventory or logistics viewpoint. In spare part business, items whose stock-out can cause severe consequences for a plant or equipment are perceived as important and thus critical items. Criticality of spare parts can be evaluated with the criteria represented in table 3.2.

Table 3.2. *Criteria of item criticality (Adapted from Molenaers et al. 2011, p. 4).*

Criterion	Description
Equipment criticality	Based on the frequency of failure the equipment and the possible consequences of the failure
Item failure probability	Likelihood of failure or breakdown of the spare part
Replenishment lead time	Total elapsed time between ordering and receiving
Quantity of potential suppliers	The number of potential suppliers of the specific part
Availability of technical specifications	The availability of technical specifications (such as CAD drawing, bill of materials, or order text) of the item
Maintenance type	The type of maintenance performed on the equipment

Huiskonen (2001, pp. 127-129) writes that using several classification parameters is especially useful with spare part inventories because the parts have various characteristics. He mentions criticality, specificity, demand pattern, and part value as the most relevant control characteristics. Criticality is defined as the most common spare part classification parameter. Item criticality can be divided into two perspectives which are process criticality and control criticality. Process criticality refers to the consequences a part can cause in a failure or shortage situation. The degree of process criticality can be defined for example by relating it to the time in which the failure has to be corrected. Control criticality refers to the predictability of failure, the number of spare part suppliers, and lead times. From the logistics management point of view, the most important factor is how much time there is to react to the demand. This factor determines in which location to keep the stock. In case of immediate demand, procedure of local stocking is usually used. Conversely, in situations where there is more time, stock can be kept on higher level of the supply chain.

The demand pattern of an item consists of the factors of volume and predictability. In spare part inventories, there are typically items with low and fluctuating demand which makes the management more difficult. Items with low volume are usually stored back in the supply chain and they should be centrally located. Predictability of demand should be divided to at least two categories, for example items with random failures and items with a predictable wearing model. In addition, high value of item favors stocking backwards in the chain. Items with high specificity are often ordered in make-to-order basis, and that is why the lead times for these items are usually long. With long lead times, safety stocking becomes a necessary procedure. (Huiskonen 2001, pp. 130-131.)

Paakki et al. (2011, p. 167) propose a more general framework for the classification of spare parts. The framework is based on the three aspects of inventory management described in chapter 2.3. It consists of two links which are supply link between supply and internal process aspects and demand link between demand and internal process aspects. Managers should take these aspects into account when deciding the most important factors. Supply link classification can include factors such as availability risk and lead time variance. Demand link classification can consist of purchasing price and variability of demand. These link classifications can include more than one factor but it is important to consider carefully how many factors should be used in the framework. Higher amount of factors give more precise control possibilities but it can easily lead to a highly complex situation. The same consideration should be done also with factor ranking which refers to how many ranks one factor has. In addition, data availability and format should be taken into account in decision making. When suitable classification factors are decided, the factors are combined into a class matrix.

3.5. Management approaches for spare parts control

Botter and Fortuin (2000, p. 661) state that in multi-echelon spare part systems, managers must answer three questions. First of all, they have to determine which spare parts need to be stocked. The second question is how many units to keep in stock for each item. And the third one is where to stock these items. This refers to the problem of which parts should be stocked in which location. Based on item classification and the previous questions, companies must determine management approaches for different segments.

Driessen et al. (2010, pp. 17-20) mention the same three questions as most important aspects of spare parts control. They have created a framework for the planning and control of spare part inventory. The model consists of three different process steps including the main tasks and decisions. The first step is item classification and determination of stocking strategy. In this phase the spare part assortment is segmented into different sub-sets which all have different stocking strategies. The basis of segmentation can be for example part criticality and supply characteristics such as part price. The second step is selecting spare part replenishment policy. This refers to the decision how often the inventory is reviewed. Both continuous and periodic review policies have advantages and disadvantages. The timing and frequency of replenishment orders need to be decided as well. The third inventory planning step is determination of replenishment policy parameters. In this step, managers must define different replenishment policy parameters for different spare part segments because critical and non-critical parts require different replenishment parameters. For instance, relatively expensive non-critical parts should have low inventory levels and critical parts should have replenishment parameters that aim to a predefined service level. When determining a replenishment model, managers should pay attention to characteristics such as network structure with multiple echelons and items, possible emergency shipments from central depot, lateral transshipments, and multiple service level criteria.

Managers are often faced with the problem of forecasting required inventory levels for items for which there is no previous history data available. This is the case with new item introductions. One possible approach is to assign sales personnel to estimate the future demand until the history data begins to develop. They have the required contacts and information to make most accurate estimation of the demand. Once history data has increased to sufficient level, more sophisticated forecasting methods can be used. Other way to estimate future demand of new items is to exploit demand pattern of similar products. This is the best way especially when the new item is a replacement for previous item. (Ballou 1999, p. 295.)

Silver et al. (1998, p. 475) describe that in a low demand environment, such as spare part business, each node of the system would typically hold at least one piece of item at issue. In this case the system is viewed from the single level perspective. But when using multi-echelon models, the whole system is perceived as one complex. Recommendation of these models might be to hold only few pieces in central warehouse and none in the branch warehouses. With this kind of solutions, system wide savings can be extensive.

Botter and Fortuin (2000, p. 665) have developed an eight-dimensional stocking strategy which can be used when determining where to keep stock in a multi-echelon spare part system. The classification criteria are consumption in units, item price, and the response time. These criteria form a cube which consists of eight segment cubes. The model is presented in figure 3.10.

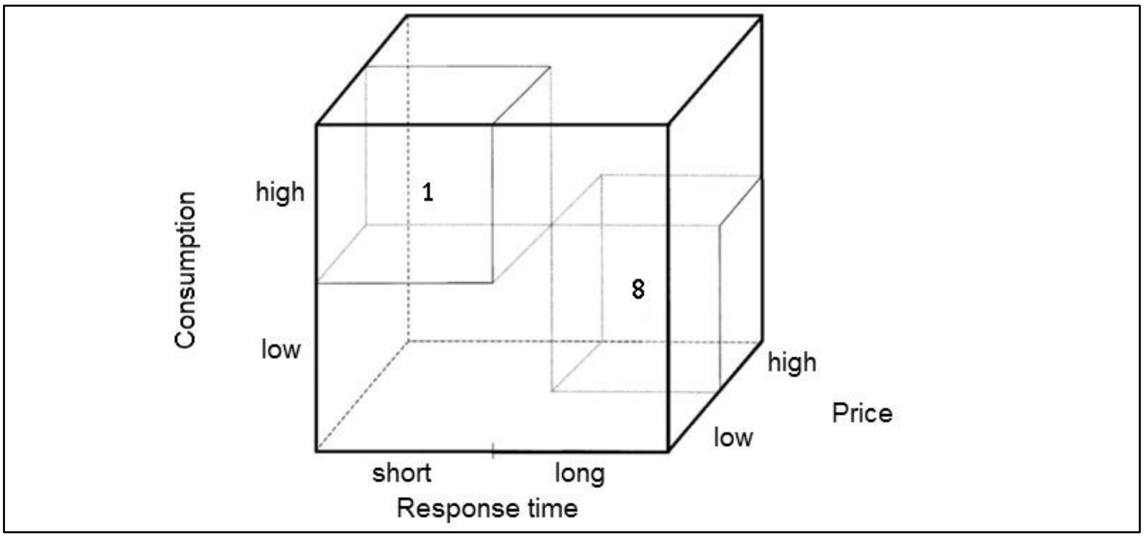

Figure 3.10. *Eight-dimensional stocking strategy in multi-echelon inventory system (Adapted from Botter & Fortuin 2000, p. 666).*

Consumption is chosen to the model because it is an important and fundamental factor in spare part inventory management. Price is important factor as well because it is not desirable to keep very expensive items in every local warehouse. In many cases it is reasonable to stock expensive items centrally and thus minimize the amount of stocked units. Response time refers to the time that is allowed to supply an item to the customer. It depends on the valid service contracts. Each of the eight segments formed by these factors represents a certain group of items and each segment has its own approach. (Botter & Fortuin 2000, pp. 665-666.) The segments and corresponding approaches are described in table 3.3.

Table 3.3. *Possible approaches for the eight segments (Adapted from Botter & Fortuin 2000, pp. 665-666).*

	Price - Response time - Consumption	***Approach for the segment***
1	Low - short - high	To be stocked in large quantities in local warehouses (close to the market).
2	Low - short - low	Also to be stocked in local warehouses but in lower quantities.
3	Low - long - high	Inventory and transport costs should be investigated in order to decide between central or local stocking. Local stocking of fast moving items could decrease the transport costs because larger quantities can be shipped by cheaper transportation methods.
4	Low - long - low	To be stocked only in central warehouse.
5	High - short - high	These items need tight management because stocking is expensive. Items should primarily be stocked in local warehouses. Quantities should be as low as possible and depend on the desired service level.
6	High - short - low	Also these items need tight management. One possibility is to stock in central warehouse and use fast transportation methods, even if it is expensive. This reduces inventory costs.
7	High - long - high	This segment needs closer investigation. Managers must decide whether to stock in central or local warehouse.
8	High - long - low	To be stocked centrally at central warehouse and shipped by regular means of transport when needed.

In addition, Huiskonen (2001, p. 131) mentions one possible multi-echelon system strategy for spare parts with very low volume. In a case where there are few relatively closely located users of a high-valued item, method of cooperative stock pooling can be used. In this method, the safety stock of an item is hold in premises of only one user and then possibly delivered from there to other users. This means that every user does not need to keep all of the low volume items in stock and thus the cost of carrying is divided. But in order to make this method efficient, inventory and demand information needs to be transparent for all operators. Paterson et al. (2011, p. 125) state as well that this method allows members of the same echelon to lower inventory levels and costs while achieving desired service levels.

In cooperative stock pooling the shipments between members of same echelon are known as lateral transshipments. Generally, there are two ways to use lateral transshipments. They can either be restricted to take place only at predetermined times before the demand is realized, or they can be used at any time. These methods are known as proactive transshipments and reactive transshipments. The latter option refers to emergency situations where lateral transshipments are used to respond to stock-outs. Reactive transshipments are often faster than normal replenishments from the supply source but they also produce additional costs. This kind of method is suitable for environment where the transshipping costs are relatively low compared to the shortage costs and costs of carrying large inventories. This is often the case for instance in spare part business. In addition, companies must bear in mind that systems with lateral transshipments are more complex to control. It is also important to compose well-defined rules and instructions for lateral shipments in order to assure that the shipments really benefit the supply chain as whole. (Axsäter 2006, p. 193; Paterson et al. 2011, p. 125.)

3.6. Performance measurement

The basic objective of inventory management is to ensure that the customer gets the right item at the right time. In order to achieve this objective, companies must assure accuracy, quality, cost efficiency, and timeliness of the inventory management process. Thus companies must set objectives for their operations and measure the performance. It is also said that what one does not measure, one cannot manage. First of all, measures are used to see how well objectives are being achieved. Measures are also used to compare current performance to former performance or to performance of other organizations. With measurement results, companies can highlight areas that need improving, make decisions about investments and changes, and evaluate effects of changes. (Waters 2009, p. 436, pp. 452-453; Richards 2011, pp. 229-230.)

Legnani and Cavalieri (2009, p. 661) have determined three aspects that need to be considered when creating performance measurement system. These are customer perspective, company perspective, and service network. Customer perspective is measured in terms of customer perceived value while company perspective includes characteristics such as profitability and investment strategy. Service network refers to the measurement of operational results. Conversely, Richards (2011, pp. 235-236) has highlighted four areas that should be measured within warehouse systems. The areas are reliability, flexibility, costs, and asset utilization. However, different companies in different fields of business have different perceptions of what is important in terms of performance measurement. Thus important key performance indicators (KPIs) vary among companies.

The main advantage of KPIs is their capability to summarize large amount of complex data into meaningful values and information. However, this includes the challenge of acquiring the most important data from the vast amount of available information. Data collection includes problems such as KPI inflation and control issues, lack of consistency, and KPI errors. KPI inflation means that management creates too many KPIs whose significance is too low compared to the required effort. This can also cause overlapping measurements and control issues. It is also important to assure consistency among KPIs because inconsistency can result in serious errors in decision-making. Errors can be caused also by inaccurately specified data. Thus key values must be defined carefully in order to assure comparability over time and across different functions. (Hoppe 2006, p. 445.)

According to Richards (2011, pp. 235-236), the following aspects need to be considered in order to choose the most appropriate measures and to make the most of them:

- What is the nature of business and strategy like?
- What are the objectives?
- Which KPIs are suitable to assist in achieving the objectives?
- Choose only measures that can be implemented and measured.
- Choose common industry measures so that the results can be benchmarked.
- Choose measures that do not cost more to manage than the likely savings are.
- Assure that everyone works towards achieving the targets.
- Review the data regularly and make sure the data is utilized.
- If targets are not achieved, analyze the reasons and develop the processes.

Waters (2009, p. 450) adds also that measures should be objective. This means that measures must give results that are not influenced by internal or personal factors. The chosen measures should also be difficult to manipulate in order to avoid false results.

3.6.1. Service level

Customer service level can be defined as the probability that demand will not be higher than supply. In order cycle this means that demand will not be higher than supply during order lead time. (Stevenson 2007, p. 564; Waters 2009, p. 355.) Although providing perfect service level to customers is a desirable target, service level needs to be balanced with the cost of providing that service. This must be done because the cost of providing service rises outstandingly the closer service level gets to 100 percent. For example, the cost of an increase in service from 95 percent to 100 percent would be substantially greater than between 70 and 80 percent. This cost difference is caused by the procedures needed for high service level. In service level of 100 percent, company would have to keep extremely high inventory levels and triple check every single order that is dispatched. (Richards 2011, p. 232.) Thus it is not always reasonable to strive for that high service level. The relation between service level and service cost is represented in figure 3.11.

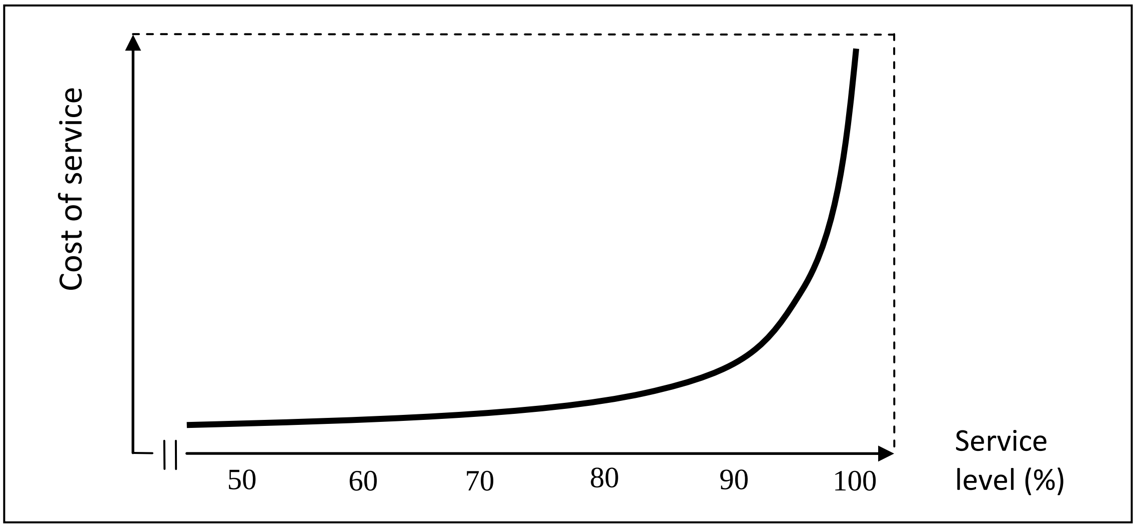

Figure 3.11. *Growth of service cost (Adapted from Richards 2011, p. 233).*

According to Bowersox et al. (2002, p. 286), service level measurement includes usually indicators such as order lead time, order fill rate, line fill rate, or a combination of these. Order lead time refers to the time between ordering and reception of shipment. Order fill rate defines the percent of customer orders filled completely and respectively, order line fill rate is the percent of order lines filled completely. These are calculated as follows:

$$Order\ fill\ rate = \frac{Orders\ delivered\ as\ complete}{Total\ number\ of\ orders} * 100\%$$

and

$$Order\ line\ fill\ rate = \frac{Order\ lines\ delivered\ as\ complete}{Total\ number\ of\ order\ lines} * 100\%$$

Other service level measurement include for instance percentage of on-time shipments which informs how many of the orders where delivered as per customer’s requests. In addition, one common customer service measure is OTIF which is a combination of on-time shipments and orders delivered in full. OTIF is calculated by multiplying on-time shipments rate with order fill rate. Quality of service is an important factor as well. This can be measured for example with number or portion of deliveries with complaints, returns, redeliveries, or incorrect quantities. (Hoppe 2006, pp. 261-266; Richards 2011, pp. 238-239.)

3.6.2. Inventory efficiency

Managers have various performance measures that they can use to evaluate the effectiveness of inventory management. One reason for performance measurement is that value of items can decrease when they are kept in stock for a long time. A particular problem in these situations is obsolescence which means that items are kept in stock so long that they have only little value or no value at all. For example spare part item can be replaced by newer version which makes the old version useless. There is also a growing trend of shorter equipment life cycles and therefore risk of obsolescence is higher. Managers want to avoid obsolescence and thus they try to keep inventory items moving as fast as possible. (Waters 2009, pp. 343-344.)

Inventory movement can be measured by inventory turnover. This measurement, also known as stock turn, is a widely used performance indicator which measures the ratio of annual COGS to average inventory value. Thus inventory turnover indicates how many times the inventory is sold during one year. (Bowersox et al. 2002, p. 560; Stevenson 2007, p. 544.) Silver et al. (1998, p. 16) define inventory turnover as:

$$Inventory\ turnover = \frac{Annual\ sales\ at\ cost\ (€)}{Average\ inventory\ (€)}$$

Bowersox et al. (2002, p. 560) remind that in the computation of turnover, it is important that the value of average inventory is determined by using as many data points as possible. This comment is valid because average inventory can vary substantially during one year. Thus using only few points would be misleading to management.

Generally speaking, the higher the inventory turnover value, the better because that indicates more effective use of inventory. Regardless, the desired turnover rate depends on the profit margins. If profit margins are higher, a lower turnover rate is acceptable. And conversely, the lower the profit margins, the higher the accepted inventory turnover. However, the turnover must be considered from the overall point of view, that is to say the concept of balancing inventory investment and customer service. (Stevenson 2007, p. 544.) One notable fact is that inventory turnover rates differ significantly between manufacturing and after-sales services supply chains. According to Cohen et al. (2006, p. 132), in manufacturing supply chains the turnovers vary usually between five and sixty, while after-sales services can have rates from one to four. In the latter type of supply chain, inventory turnovers of one to two are common and 23 percent of parts become obsolete annually. Another benchmarking study by Cohen et al. (1997, p. 653) illustrates that inventory turnover of spare parts was consistently low across the subject companies. The sample average was 0,87 and the highest value around two.

Waters (2009, p. 447) suggests a measure called average total inventory value. It can be calculated by multiplying average stock amount of an item by its unit value and summing the results of all items. The formula is:

$$Average\ total\ inventory\ value = \Sigma(average\ stock * unit\ value)$$

The average stock amount is used because the amount of kept stock can vary quite widely over time. However, there is no moment when the average amount of every product is actually in stock. Thus average stocks, as well as the unit costs, are only estimates. (Waters 2009, p. 447.)

4. CURRENT INVENTORY MANAGEMENT

4.1. Cargotec Services' spare part logistics

The purpose of this sub-chapter is to present the spare part network and operations of Cargotec Services. It consists of introducing the supply chain structure, different parties, and supply process. The data of this chapter was collected by observation and interviewing Cargotec Services personnel at Central Operations. Internal statistics, documents, and presentations were used as well.

4.1.1. The supply chain of spare parts

In the research case of this thesis, Cargotec Services' spare part supply chain includes four levels. It consists of suppliers, Central Operations, front line, and customers. From Cargotec's point of view, the chain is a two-echelon spare part inventory system. Central Operations, including DCs, form the first echelon and front line units the second echelon. In this thesis, front line consists of regional sales offices. The supply chain of Cargotec's spare parts is illustrated in figure 4.1.

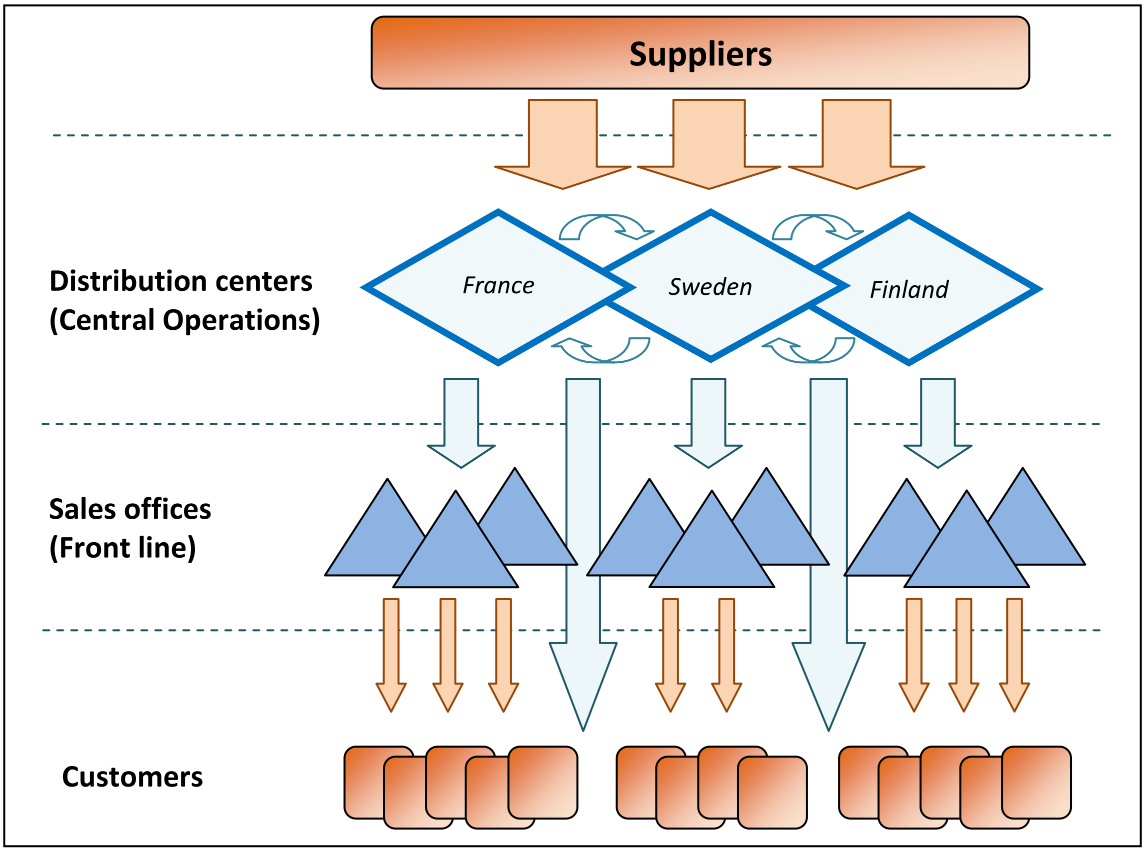

Figure 4.1. *The supply chain of Cargotec's spare parts in EMEA-region.*

In practice, there can be even more echelons because front line can consist of various stocking locations such as warehouses and maintenance vans. But because the structure varies between different front lines, it is simplified at this point. Cargotec's Central Operations purchases spare parts from suppliers who in most cases ship ordered parts to Cargotec's DCs. There are currently around x active suppliers. Direct shipments past DCs are used only in special cases such as deliveries of large frames. When parts arrive from supplier, DC's personnel receive the parts. This phase includes possible repacking into Cargotec brand packages and shelving to the stock. If received parts have already a sales order waiting, cross-docking is used and parts go straight to shipping process instead of being physically shelved. When parts are ordered by sales offices, they will be picked and packed into predetermined shipping packages and shipped to consignee. Sales offices are in direct contact to the end customers. They are also responsible for supplying the parts to customers. On the other hand, it is possible to deliver spare parts to customers directly from the DCs. Cargotec Services' customers are cargo handling equipment users in industries such as ports and terminals, manufacturing, distribution, and recycling.

The spare parts distributed by Cargotec Services' supply chain include various types of components. Firstly, there are major and key components. Major components include for example engines, gearboxes, and shafts, whereas key components include pumps, valves, cylinders, and wheel rims. Second group includes electrical items such as central processing units, switches, sensors, circuit boards and programmed units. Third item group consists of wear parts, consumables and servicing items. Wear parts include for example slide plates and bearings whereas consumables and service items are such as oils, greases, bulbs, and nuts. In addition, Cargotec's spare parts include accessories and upgrade components.

4.1.2. Central Operations and warehouses

Cargotec's Central Operations are responsible of functions such as inventory management, logistics management, purchasing, and sales support of spare parts. The most relevant functions, from this research's point of view, are inventory management and logistics management. These functions are handled by central planning organization, and warehouse and transportation organization. Central planning is responsible for activities such as inventory management optimization and parameters of spare part inventories. Warehouse and transportation organization is responsible for daily coordination of warehousing and the inbound and outbound logistics.

Cargotec Services has three different spare part DCs in EMEA-region. First one is European Distribution Center (EDC) which is located in Metz, France. This DC includes both Terminal inventory EDC and Load Handling inventory P200. The second warehouse, Nordic Distribution Center (NDC), is located in Stockholm, Sweden. Also NDC consists of two inventories which are Terminal inventory F37 and Load Handling inventory P100. The third DC is AS which is located in Tampere, Finland. The locations of these three DCs can be seen from figure 4.2.

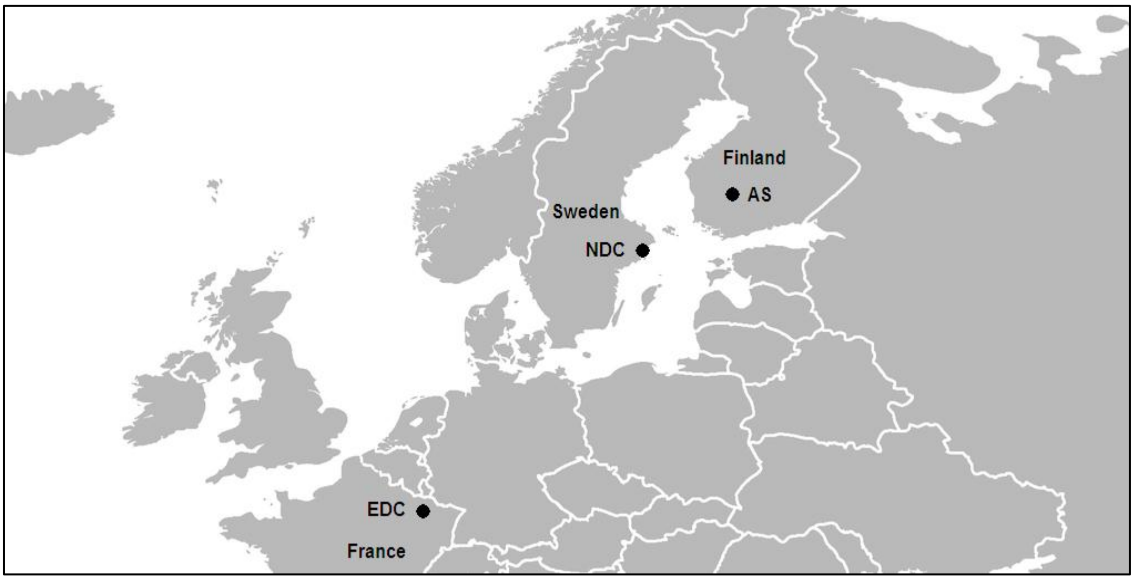

Figure 4.2. *Cargotec services' DCs in Europe.*

Operative warehousing of Cargotec Services' spare parts is outsourced. Thus all three DCs are operated by an external service provider. Caterpillar Logistics Services is responsible for operating EDC and NDC warehouses, and AS warehouse is operated by Vindea Oy. The DCs are also focused on different market areas. EDC focuses mainly on sales in the central European and Middle East market areas. NDC is mainly responsible for the Nordic market area and AS takes care of sales to Russia and East Baltic countries. However, these are only general terms and for example in urgent situations such as when customer demands a compensatory part, replacement parts can be send from any warehouse that has enough stock.

Cargotec Services' spare part offering includes over 650000 different item numbers. However, in the DCs there are approximately x SKUs. This number includes only SKUs of Terminal business area and same SKUs can be found in all three DCs. EDC has currently over x SKUs which is almost half of the total item amount. NDC has around x SKUs and AS around x. The distribution of items in stock is illustrated in figure 4.3.

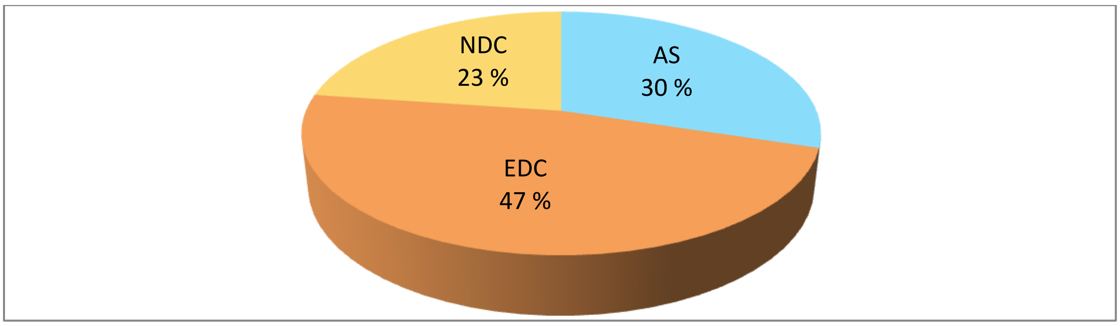

Figure 4.3. *Distribution of SKUs in different warehouses.*

4.1.3. Sales offices

Cargotec is committed to assuring continuous usability of customers' equipment. In this mission, Cargotec Services' sales offices are in important role. The sales offices are responsible for delivering service solutions to customers in their regions. The service offering includes warranty and refurbishment work, equipment inspections, spare part service, maintenance contracts, and other customized services. Services' sale offices are focused on active customer relationships and customer satisfaction. And at the same time, they aim to achieve more service agreements and maintain customer profitability. Cargotec's service coverage in EMEA-region, in terms of sales office locations, is shown in figure 4.4.

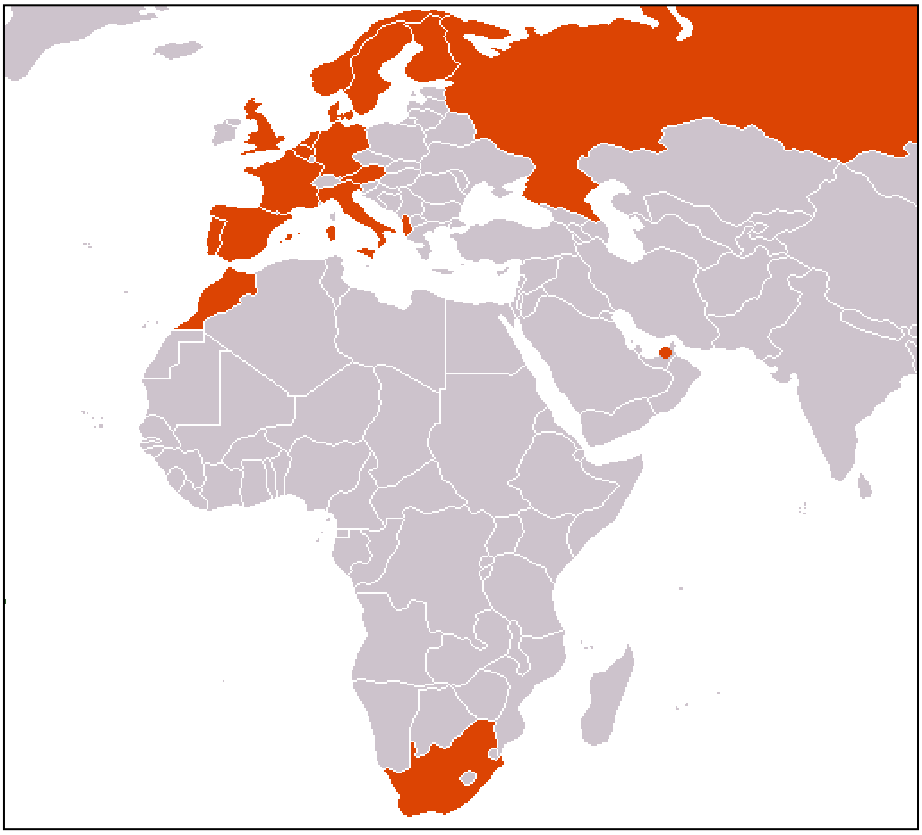

Figure 4.4. *EMEA-region countries that have Cargotec Services sales offices.*

As the previous figure shows, Cargotec's EMEA-region sales offices are located in Holland, Belgium, Germany, United Kingdom, France, Austria, Italy, Finland, Sweden, Norway, Denmark, Russia, Albania, Dubai, and South Africa. There are also Cargotec Iberia which is responsible for services of Spain and Portugal, and Cargotec Maghreb in Morocco. Some of the sales offices provide services also to various neighbour countries. For instance sales office in United Kingdom covers also Ireland, Belgium covers Luxembourg, and Austria covers many neighbouring countries. Thus the sales office network is actually much extensive than the map shows.

4.1.4. Order types

Spare part orders between the DCs and sales offices can be divided into three different types based on the type of demand. The order types are urgent orders, weekly orders, and stock replenishments. Urgent orders are used in cases where parts are needed for a machine down situation. These orders can have a maximum of ten order lines. In all urgent cases the ordered shipments are sent by the fastest reasonable transportation method. Usually this means delivery that is at the destination by next morning. In some cases, also special taxi delivery is used. Weekly orders are used when parts are needed for regular end customer order. These orders are shipped weekly, for example every Thursday, to the ordering sales office. The third order type, stock replenishment, is done to replenish consumable parts at sales offices. Delivery of these orders is done according to the agreed procedures between Central Operations and sales office.

Also lateral transhipments are used at Cargotec Services but only at the first echelon, that is, between the DCs. At Cargotec, these orders are known as replenishment orders (RPLs). RPLs are made mainly because all suppliers cannot deliver parts to all countries. For example, some Finnish suppliers deliver parts first to AS-warehouse and these parts are then delivered by RPLs to other DCs. RPL can also be made in situations where there is more demand for the parts in another warehouse. If a part is needed from one DC and it is in stock in another one, RPL is usually a faster way to get the needed part to the correct warehouse than with a new purchase order.

4.2. Inventory management in Central Operations

As mentioned in chapter 4.1.2., Cargotec Services' Central Operations are responsible for spare part inventory and logistics management of the DCs. This sub-chapter will introduce the inventory management policies that are currently in use in Central Operations. The policies are established in order to ensure required service level and item availability while optimizing inventory costs. The data of this chapter was collected by observation and interviewing Central Operations' personnel in Tampere. Internal statistics, reports, and documents were used as well.

4.2.1. Planning process

In Central Operations, the main purpose of inventory planning is to construct optimal warehouse structure, and optimize the inventory turnover and availability by determining control parameters for items. The planning process consists of various steps which are represented in figure 4.5. At the beginning of the process, data must be collected and prepared for the analysis. The data includes basic item data and transaction data such as consumption history, cost data, and planned demand. Data is also collected from front line units. The required data types and flow of data is described more precisely in chapter 4.3.2.

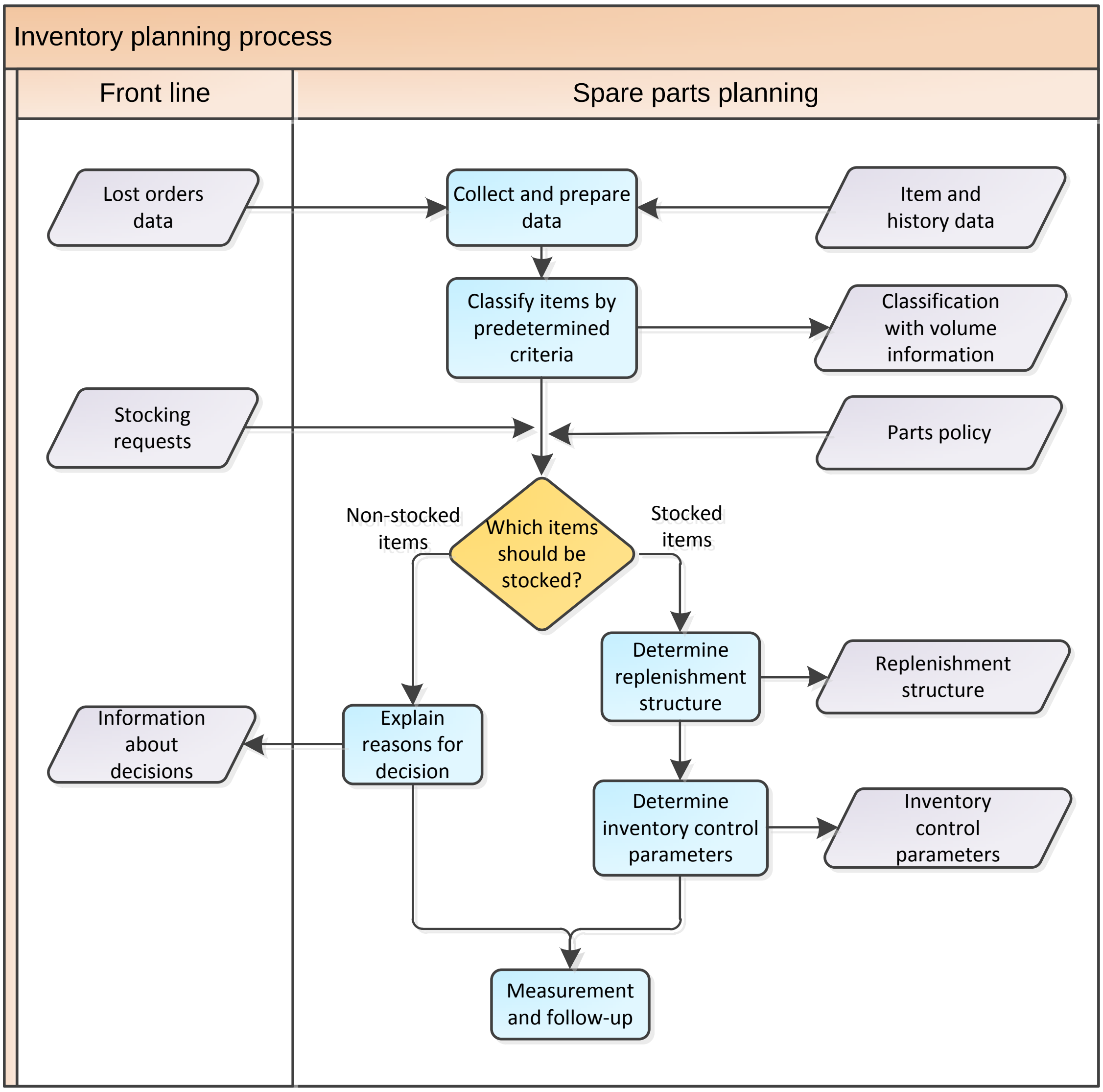

Figure 4.5. *Inventory planning process of Central Operations (Adapted from Valonen 2011).*

The next step is item classification which is done by analyzing the collected data. Classification is an important phase because it will give the basis for inventory management and steering. The classification is based on three factors which are demand frequency, monetary usage, and criticality. Spare part classification methods are described in chapter 4.2.3.

When item classification is done, stocking policies must be decided. This means that spare parts planning must decide the rules for whether or not different items should be kept in stock. The decisions are based on the previously done classification, sales history, and parts policy. Spare part planning needs to estimate the population of customers' equipment and target volume of spare parts. This phase includes also defining service level targets and optimizing inventory costs. In this phase, new products and changes in existing products or customer contracts must be taken into account. In addition, spare part planning must also communicate with sales and consider possible stocking requests. Sales can make requests with tool in internal database. More information about stocking decisions and service level targets can be found from chapter 4.2.3.

Decision reasons for items, which were requested to be stocked by front line but will not be stocked, need to be explained to the front line unit in question. This should be done in order to enhance cooperation and information transparency between different parties. It is important to communicate reasons for all parties in order to develop the whole inventory system. As for the parts to be stocked, spare parts planning must determine replenishment structure for front line. The structure includes replenishment instructions such as will the front line be supplied from the DC or directly from the supplier.

The final step is determining inventory control parameters for the DCs. These parameters include for instance reorder points, safety levels, and order quantities. Predetermined item classification is used when defining the control parameters because it has for example different service level targets for different classes.

4.2.2. Inventory management software

Parameters of Central Operations’ inventory management are controlled with Servigistics software which was implemented in December 2010. Servigistics is an enterprise software solution for service lifecycle management. It is connected to Cargotec’s ERP-system and together they form the basis for the spare part operations and control. Cargotec’s Central Operations use currently ERP-system called Baan but in future the system will be SAP which is currently being implemented. SAP is already in use in some sales offices, for example in Belgium, and it will be fully implemented during year 2012.

The information flow of the programs is a continuous cycle that begins when ERP-system transmits all required item-related data to Servigistics. The transmitted data can be seen from figure 4.6. With this data, Servigistics calculates inventory control parameters for parts and then transmits them to ERP-system. Servigistics is currently set to transmit only ROP, EOQ, expected annual usage, and classification information to ERP-system. Thus Servigistics determines whether or not item is stocked in the DCs. In future, Servigistics might be exploited even more in the inventory control. When ERP-system receives the up-to-date control parameters from Servigistics, it makes the necessary purchase impulses in order to replenish stock to required level. This level is a sum of safety stock and EOQ. The foregoing cycle of information processing is done once per day. Information transmitting is constricted so that ERP-system does not feed data from items which do not have transactions from the past three years.

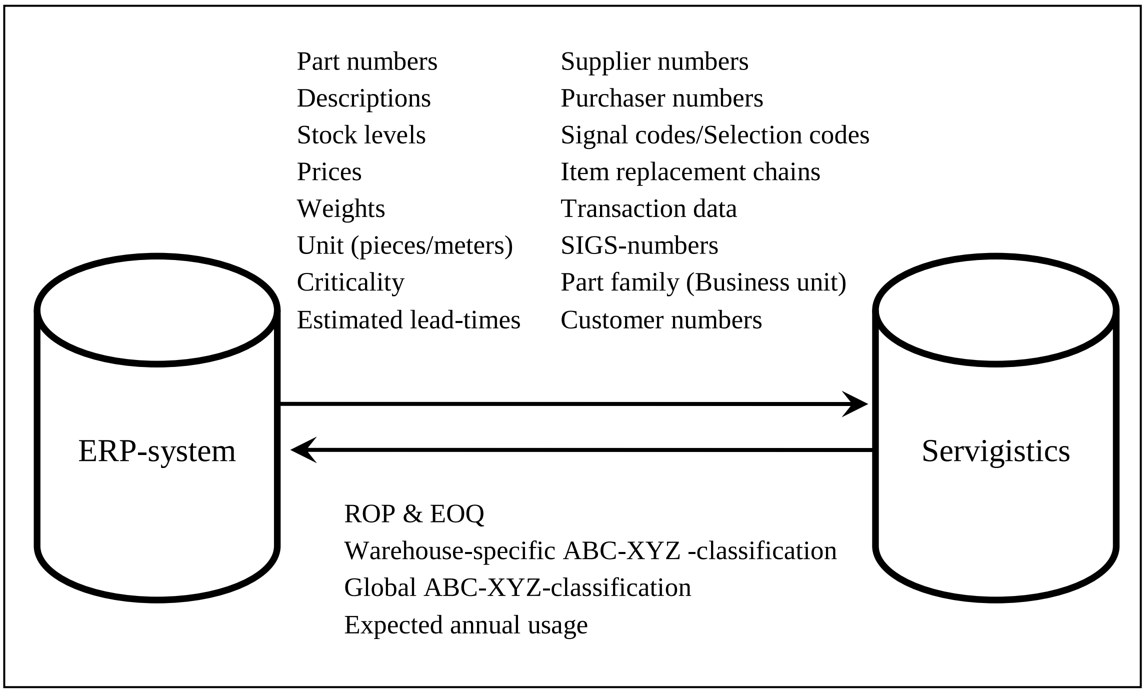

Figure 4.6. *Data flow between ERP-system and Servigistics.*

Servigistics calculates and controls also safety levels and lead times which are needed for calculation of ROP and EOQ. Required safety level of an item depends on the variation of lead time and demand. First of all, Servigistics calculates the mean value of lead time by using purchase history data from past two years. The basic requirement is that there have been at least three purchase orders. In Servigistics, lead time is defined as elapsed time in days between the ordering date and the date when item is available for sales. After this, Servigistics calculates the standard deviations of order lead time and demand sizes. The larger the standard deviations are, the higher the required safety stocks are. In addition, Servigistics continuously adjusts and predicts ROPs if demand amounts have peaks or irregularities.

In Servigistics, every customer has a predetermined home warehouse which will be informed to Servigistics by customer number. For example, if Sales office in France makes an order, the ordered items are primarily dispatched from EDC. It is also possible to make an order to France from AS or NDC but in every case, the demand information is directed to the home warehouse. Thus sales from different warehouses are always counted as sales from the predetermined warehouse.

Central planning organization can also adjust the parameters in Servigistics manually. Manual adjustment is needed for example if a new product is introduced and it has critical parts which need to be stocked. In this case there is no available transaction history data and thus item is not stocked without special actions. In order to get inventory parameters adjusted, sales representatives make requests to central planning who can access Servigistics.

Cargotec Services uses Microsoft's SharePoint collaboration software in communication with sales personnel and product support. In SharePoint there are two important inventory planning related databases. These are inventory parameters database and product support database. In inventory parameters database, sales representatives can make requests for item stocking, item criticality, and parameter modification. First sales representatives create a case to the database and choose an issue for it. They also fill the other required information such as part number, estimated annual consumption, ROP, order quantity, and lead time. When the case is created, it will appear in open status to central planning. Then central planning examines the case and makes adjustments if necessary. The inventory parameter case number will be marked also into Servigistics, so that the cases and made adjustments can be linked later to each other. An example of inventory parameters case is shown in appendix 2. It includes also detailed instructions for creating a new inventory parameters case.

Product support database is a recently created tool for collaboration between product support, spare part sales, and central planning. Product support cases are created in SharePoint by product support personnel because they know the latest information about Cargotec's equipment and parts required in the service. In appendix 3, there is an example of this kind of case. The purpose of product support cases is to inform Central Operations about updates of equipment service requirements. In Central Operations, few persons are nominated as responsible for different product families such as straddle carriers and terminal tractors. These persons are notified about product family updates by the product support case when the case status is changed to pending parts sales. These nominated persons are responsible of preparing the items and data for central planning. This means that all related items are opened and that all required item data is entered to the ERP-system. When items and related data are prepared, the case status is changed to pending planning, when it is their turn to act. Central planning analyzes the request and then modifies inventory parameters in Servigistics if necessary. When changes are done, the case is closed. Utilization of product support database is still in early stage and it is used only in Central Operations. However, in future product support database can be implemented also in sales offices.

4.2.3. Item classification and stocking decisions

Cargotec Services' Central Operations use a combination of ABC- and XYZ-classification methods in inventory management. Cargotec's ABC-classification principle, which is based on the monetary usage, is illustrated in figure 4.7. Inventory items are classified by the share of monetary usage which is measured by COGS. The computation takes into account sales from past 15 months. The classification begins with A-class items which account for the first 80 percent of the usage. B-class items bring the next 15 percent and C-class items the final 5 percent. Items, that have been stocked during a certain period but have not been sold, are categorized into class D. Thus these items do not make any revenue but only costs to the company.

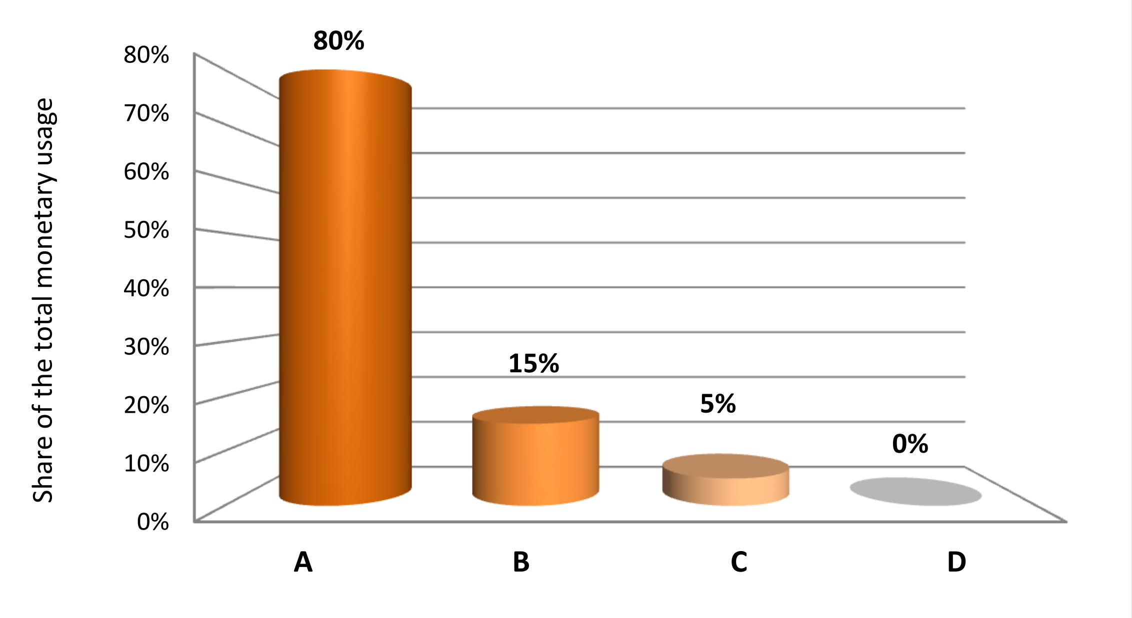

Figure 4.7. *ABC-classification principle of Cargotec Central Operations.*

The XYZ-classification of Cargotec Services' Central Operations is based on number of sales transactions in last 15 months. Thus the category of an item is determined by how many times the item is sold and it describes the order frequency. The XYZ-classification principle is shown in table 4.1. Items in X-class are sold more than 50 times in last 15 months, Y-items 12 to 49 times, and Z1-items 3 to 11 times. These classes have items that are stocked. Items in class Z2 are sold only 1 to 2 times per year and N-items have no transactions. Items with these transaction amounts do not get stocking impulse. VOV, which is a default code for new items, is given when a new item number is opened. In addition, items will also be removed from the stocked items if they do not get enough transactions. However items, which are marked as critical, will remain stocked although they do not have enough transactions.

Table 4.1. *XYZ-classification principle of Cargotec Central Operations.*

Class	**X**	**Y**	**Z1**	**Z2**	**N**	**VOV**
Transactions (order lines) per 15 months	≥ 50	12-49	3-11	1-2	0	-

Item can be stocked also if it has been defined as critical part. Criticality is a simple, 0/1-type of adjustment which has no multiple levels. Criticality marking can be created for example if the item has a long lead time. Second factor is item's importance to the equipment. This refers to the consequences that the item can cause in shortage situation. Thus from this point of view, criticality is defined based on the time in which the failure has to be corrected. Critical parts are normally slow moving parts that need to be stocked due to business reasons.

The previously described XYZ-classification is the basis of Central Operations' stocking policy. There are three different possibilities for an item to become stocked item. First of all, item will be stocked automatically in a DC if it is sold at least three times in 15 months to the market area of DC in question. The second stocking decision is based on global sales transactions. Item will be stocked if it has four or more transactions globally in 12 months. This takes into account sales transactions from all DCs. The principle behind this option is stock pooling. Thus if there are for example one transaction from each warehouse for an expensive item, there is no point to stock item in every warehouse. In this case one DC is chosen as stock pooling location. Even if item does not meet either of the previous two requirements, it can still be stocked if stocking is proposed by sales because they might have relevant information about the future sales of different items in their market area. The whole stocking policy of Central Operations is illustrated in figure 4.8.

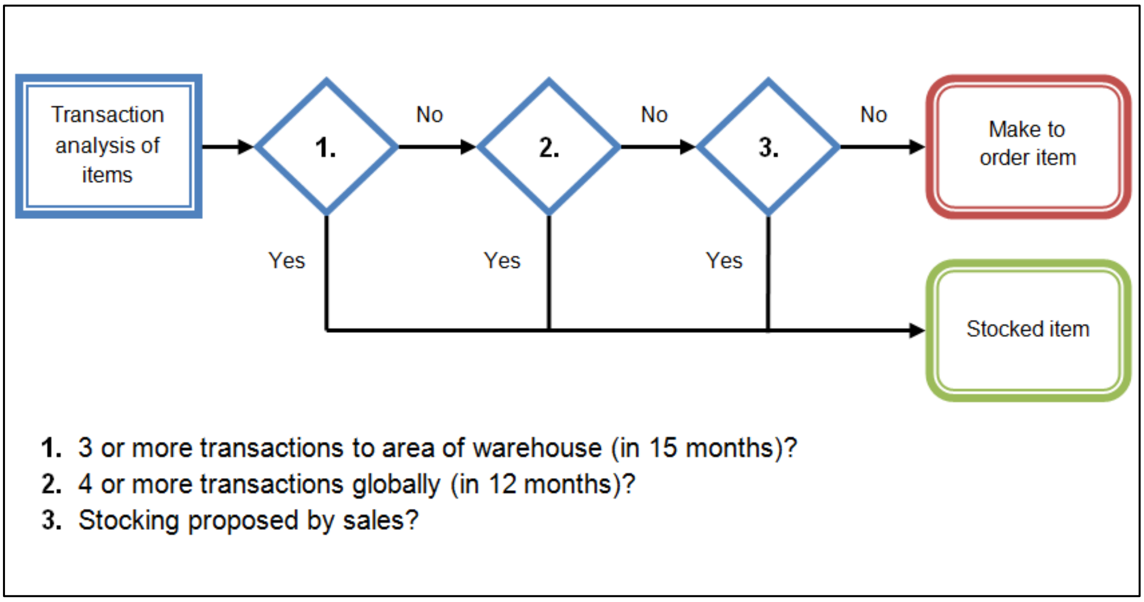

Figure 4.8. *Stocking policy of Central Operations.*

The stocked items in the DCs consist mainly of classes X, Y, Z1, A, B, and C. In Servigistics, these classes are combined into a matrix where one axis is formed by X, Y, and Z1, and the other axis by A, B, and C. This matrix forms nine different classes which determine the required service level for the parts. These control parameters are flexible and thus levels can be modified if necessary. The classification and current order line fill rate targets are presented in figure 4.9. Servigistics uses two different methods for order line fill rate calculation. Type I, which is used for other classes but A/Z1, is calculated so that when there is an order line of ten pieces and only nine are available in stock, the fill rate is zero percent. So the line must be delivered directly as complete. In the same situation, type II calculation would give a fill rate of 90 percent. So in this case the order line fill rate is computed by dividing the available pieces with the ordered pieces. This calculation method is currently used for class A/Z1.

Sales transactions (15 months)	**XYZ**					
0	**N**	-	-	-	-	
1-2	**Z2**	-	-	-	-	
3-11	**Z1**	x %	x %	x %	-	
12-49	**Y**	x %	x %	x %	-	
≥ 50	**X**	x %	x %	x %	-	
		A	**B**	**C**	**D**	**ABC**
		80	*15*	*5*	*0*	*Percentage of the total COGS (15 months)*

Figure 4.9. *Item classification matrix and current order line fill rate targets.*

One important aspect of inventory management is how to manage non- or slow-moving items. At Cargotec Services, non-moving item is defined as item which has not had any sales within two years. Non-moving inventory can be resulted from various reasons. For instance, manufacturing of a certain product model has been stopped or item has been replaced by a new one. It is also possible that there has been an incorrect order or forecast, customer has cancelled an order, or the item is not mentioned in spare part book. Non-moving items are a problem because they form x percent of the total inventory value. Thus stocking of non-moving items is a significant investment which has to be activated. Conversely, slow-moving item is defined at Cargotec Services as an over-stocked item that has an inventory turnover of lower than 0,5. Slow moving items can belong to any of classes A, B, and C.

In accounting, non-moving inventory is considered as expense, and it has negative effect on the result. Thus it is important to identify obsolescent inventory and write these items off. One obsolescence definition is the previously mentioned case where item has not had sales transactions during previous 24 months. Additionally, also excess stock can be defined as obsolescent inventory. Excess stock exists when an item has more pieces in stock than what is the estimated 24-month use. However items, which have been purchased during last 12 months, are excluded from this group, because they are most likely new items.

4.2.4. Performance measurement

Performance measurement and follow-up of progress are in important role when managing spare part inventories. In Cargotec Services' Central Operations, performance is measured from three different aspects which are inventory value, inventory movement, and service level. These key areas are monitored with reports that are processed daily from Cargotec's report tool called KIRC (Kalmar Industries Report Central). The reports are used to follow-up trends of inventory characteristics. In order to generate comparable trend data, it is important that the same calculation method is used all the time.

The first aspect, inventory value, is measured by daily total value of inventory. This is calculated by multiplying the stock on hand by item prices. The price used is the most recent purchase price. Daily total inventory value is measured in order to monitor the development of inventory value. Thus it does not have any target level but it is used to follow-up the trend. The total inventory value can be calculated individually for each warehouse unit or alternatively, as a combined amount for all units. It is also important to monitor the value of non-moving inventory, for example by calculating the non-moving inventory's percentage of the total inventory value.

The second measurement aspect is inventory movement which is measured by inventory turnover. It is calculated by dividing cost of items sold annually by current gross inventory value. This tool is used for instance when identifying the slow-moving items. It is also used in monitoring the trend of inventory movement. For example, decrease in the inventory turnover can be acceptable in cases where the inventory value is increasing. But when inventory value is decreasing, inventory turnover must not decrease. When calculating inventory turnover, it is important to separate the active inventory from the non-moving.

Also service level is monitored. This is done by measuring fill rate of urgent orders. The measuring is done in dispatching point of sales process because monitoring actual delivery times to customer is difficult. Actual deliveries could be monitored effectively only if information systems of delivery companies were integrated to Cargotec's system but this is too complex to implement. There are currently two different fill rate measures, availability and completeness. Availability represents how many lines of the whole order are immediately available. Thus, if one of the ordered ten lines is left to backorder, the availability rate is 90 percent. Conversely, completeness describes how many percent of the orders have been immediately shipped as complete. Thus the previously described situation would give fill rate of zero percent. Specific service level targets are determined separately for each item segment. Present targets can be seen from figure 4.9 in chapter 4.2.3.

There is also another follow-up tool for service level of X- and Y-items. It is known as zero lines report. It calculates the share of X- and Y-items which have no stock at the moment. Thus it is a measurement tool for possible stock-outs. The current target is to keep the percentage of zero lines below two percent but in future the aim is to lower the percentage to zero. This report is run at the end of every month. Hence it describes the momentary situation of zero lines in stock of X- and Y-items.

4.3. Inventory management in the case front line unit

The purpose of this sub-chapter is to describe the operations and inventory management process of one example front line unit. All information was collected at the front line sales office by interviewing local personnel that work within the service and material management process. The interview outline can be seen from appendix 4. The case front line unit was still in progress with their SAP implementation which is why this sub-chapter describes inventory management process from the time they still used the old system.

4.3.1. Supply network structure and customer base

Example front line unit's main premises are located nearby one of the largest ports of Europe. Thus the front line unit operates in large harbour environment and its customer base includes some of the main logistics providers of the port. In the business area of Terminal solutions, they offer wide range of different services such as repairs, maintenance, refurbishments, and spare parts supply. They have also small research and development (R&D) team who provide special applications for few customers.

Service jobs are done either at the customer's site or at Cargotec's workshop, depending on the type of machine at issue. The main premises include workshop, main warehouse, and office facilities. Besides the main warehouse, there are six smaller sub-warehouses with a purpose of enhancing customer service. The sub-warehouses are linked to the local workshops and they employ only technicians. Thus there are no warehouse workers at the sub-warehouses. In the spare part supply process, parts are first ordered to the main warehouse and then delivered to sub-warehouses or straight to customer sites. The distribution network structure is illustrated in figure 4.10.

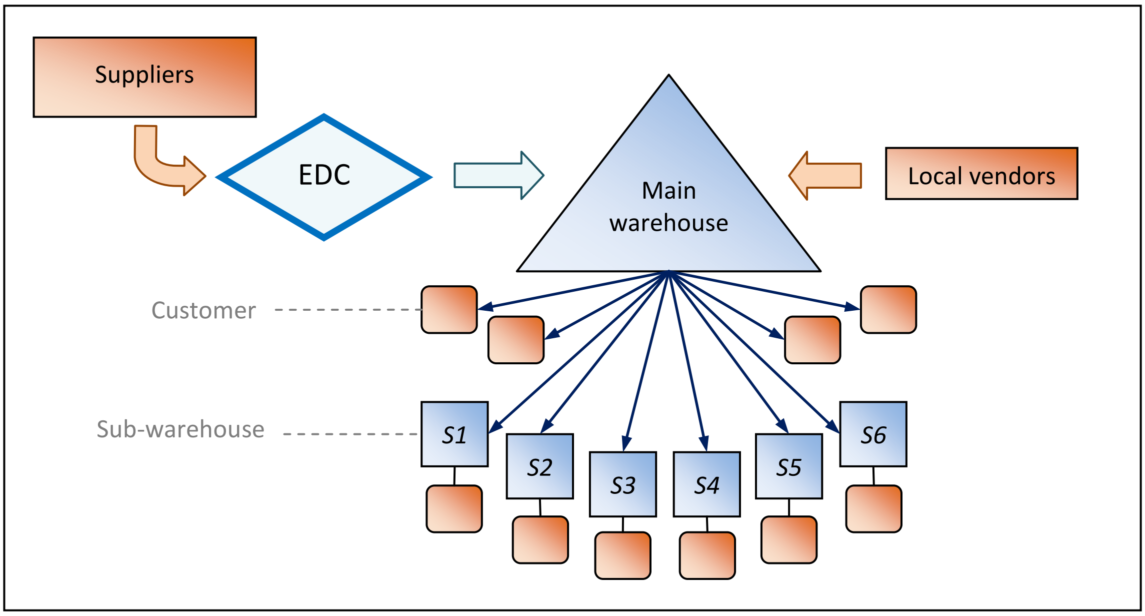

Figure 4.10. *The distribution network from perspective of the example front line unit.*

Internal purchase orders are generally urgent orders which are delivered from EDC overnight. In this case, ordered parts are received around seven o'clock in the morning. Most of the spare part deliveries to customers are done with front line unit's 25 service vans. There are many types and sizes of vans but the main purpose of these is to provide on-site service and deliver spare parts to customers. The vans handle also most of the spare part deliveries between front line's own warehouses. Usually service vans hold only small amount of inventory which consists of fast-moving consumption items.

The example front line unit orders spare parts mainly from Cargotec's Central Operations but in some cases they also use local vendors. Cargotec's general policy is to purchase parts internally and that is also where the case front line is striving for. But because of their history before Cargotec ownership, they have strong connections to local vendors and for instance in emergency situations local purchasing can be the only option to satisfy customer. Thus purchases are not done internally in every case. When a purchase order is received, the warehouse personnel receive and check the contents, and repack parts if it is necessary. Parts are then stocked or delivered to customer, depending on the urgency of supply.

The most important customer of the example front line unit is a large shipping company. It operates approximately 100 straddle carriers, which makes it a significant service client. Other important customer groups include for instance companies in steel and concrete industry. For steel companies, case front line provides also special applications designed by their R&D team. Another significant customer is a large international shipping line. What makes servicing this customer particularly complex is that they have a service contract for complete package which means that Cargotec overhauls all kinds of machines on customer's vessels. The service must be done when ships are at the port which usually means 48 hours at most. This time period is typically at weekend which means that Cargotec must have sufficient spare part stock beforehand. In addition, customer base includes machine rental and leasing companies, and also some spare part traders. All in all, the current service contract base is multiform. Business related factors are determined on a very informal basis and the cooperation between front line's spare parts department and services is often vague, which is why the contract details are not always shared with the spare parts department. Thus the front line operations and structure, in terms of spare part inventory management, are quite disorganized.

4.3.2. Ordering and inventory management

The case front line unit keeps spare part inventory in order to service its customers. Demand for spare parts comes from spare part sales and service jobs which usually require also spare part mounting. Thus when a service job is received, its part requirements are entered into the system which then defines if there is enough stock or should some of the parts be ordered. If there is no stock for the demanded part, system creates a purchase requisition for the responsible buyer. The requisition can also include item related information, such as supply source and price, which eases buyer's work. Then buyer makes the order and requested parts are delivered to the front line warehouse. At this point, when there is sufficient stock, warehouse can pick the parts for the service job or sales. In addition, the picking decreases the stock level in the system by corresponding amount.

The inventory management of spare parts is currently done by continuous review system which is based on min-max method and ROP. This means that items' stock levels update continuously in the system and when stock level drops below minimum point, it has reached ROP. At this point, purchase requisition is created and reordered quantity increases stock level to the maximum point. This method is illustrated in figure 4.11. For example if maximum is 10 and minimum 5, when stock level reaches 4, buyer will order 6 pieces. But if the piece can only be ordered for example in box of 10 pieces, then buyer will order that amount.

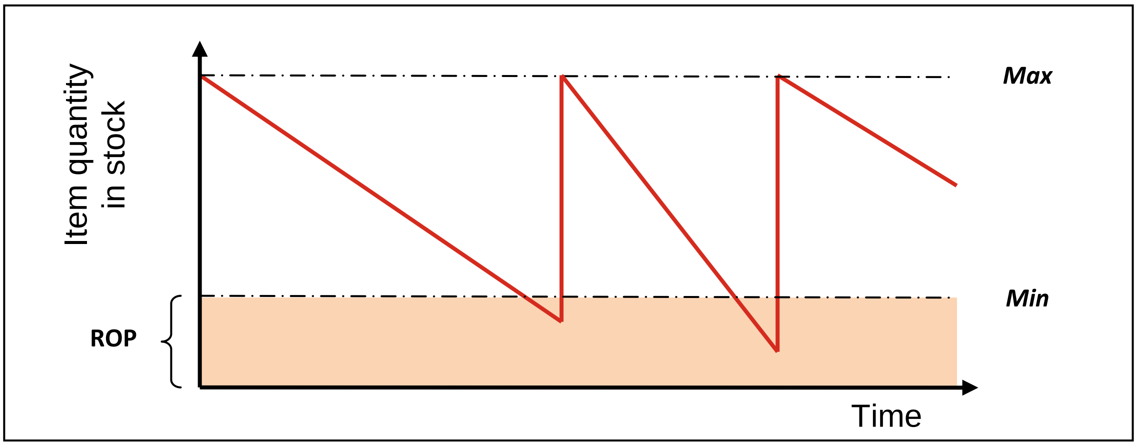

Figure 4.11. *Min-max method of the case front line unit.*

Although stock levels are updated automatically, all inventory control parameters are currently updated manually. There is not any mathematical or systematic mean for steering inventory parameters, such as ROPs and maximum stock levels, and all modifications are based on front line personnel's experience and expertise about customers' machines and service needs. In addition, item classification or EOQ calculations are not utilized. One good example of the current manual process is the parameter adjustment for batteries. When winter is coming, person in charge increases the maximum level and more pieces are ordered to the inventory because personal experience tells that in winter the consumption is higher. Normally, possible modifications to system parameters are done twice a week when person in charge reviews all SKUs which have had new purchase requisitions. Information system shows for example 12-month usage for SKUs and also into which machine they been used. With this information and personal experience responsible person modifies parameters if it seems necessary. Reviewing process takes approximately three quarters of one employee’s workday.

Also stocking decisions are done manually and based on personnel’s service experience. Stocked items and stocking locations are determined by factors such as item value, demand frequency, local market situation, and type of contract. Item value and transactions are important factor when deciding which parts to stock locally and which centrally. It is not reasonable to stock expensive, low-frequency items in local warehouses. For example, if there has been one transaction in each sub-warehouse annually, it should be enough to hold one piece in the central warehouse. But if the part in question is special and needed only by one customer or sub-warehouse, it is stocked only at that warehouse. In addition, if customers have ordered a non-stocked part repeatedly such as five times per year, it will be changed to stocked part. Local market situation refers to what kind of machine base customers have. Customer’s machine base determines generally what kind of spare parts can be needed in servicing, and machines’ age and condition helps to predict spare part demand. Contracts can be for instance leasing or servicing contracts. They affect significantly to the possessed inventory because they can include various service requirements such as maximum response time. Typically, customers want service within one day but sometimes immediate servicing is required. Contracts can also include penalties for machine downtime which call for good spare part availability.

At the moment, there is no systematic reporting system and inventory management is not measured. The only measured factor is total inventory value which can be output from the system. This statistic is updated monthly only because it needs to be reported to the finance department. Thus in fact, it is not done in order to monitor or develop inventory management. Currently there are no indicators for service level, inventory efficiency, or any other inventory related factor. However, the implementation of KPIs is currently in progress because of Cargotec’s One Programme that implements the common processes and system solution to support Cargotec’s strategy and one way of working.

4.3.3. Characteristics and challenges of the market

Some market characteristics and challenges emerged from the front line unit interview. One relevant dilemma is what items to hold in stock. This is a complex problem because Cargotec’s machine range is very diverse at the local market in question. This results partly from Cargotec’s complex history with multiple corporate acquisitions. The case front line market is also very active in terms of pre-owned machines, which means that also relatively old machines are serviced there. For example old machines can be refurbished in the front line and then sold to a market of less-developed country. In addition, Cargotec expands its product offering continuously by launching new models. Thus it is difficult to determine which spare parts of different machines should be kept in stock. For example when a new machine is introduced, front line personnel have to decide which parts they should stock right away and which parts after they have broken down in the machine. One procedure is that they check all consumable parts, such as filters, from the new machine and stock all new types which are not stocked yet.

Frequent model introductions result also in constantly changing and increasing part range, which means that new spare parts are introduced all the time and some previous parts are superseded by new ones. This evolution makes spare part operations highly prone for errors and mix-ups. That is why importance of information transparency should be emphasized. The front line needs timely and relevant information about new, updated, and substitutive parts and models, so that they can order and provide correct parts with short response time.

The example front line unit encounters high pressure in the market from their customers and competitors. Some customers are strong players in the market and they put pressure on service providers, for instance by tendering service providers. They can also have strict contracts with high shortage penalties. The competition is fierce and competitors are improving and multiplying constantly. Many competitors have lower prices which is why Cargotec needs to compete with other factors. Main competitive edge comes from response time and quality of service. Flexibility of service is important as well. For example when service technicians go to the customer site to repair a machine, they must also be able to work out problems that were not expected. These factors need to be taken into account also in inventory planning.

5. BENCHMARKING

5.1. External benchmarking

The first step of the benchmarking process was to select the process to be investigated. Because this thesis focuses on inventory management process, it was also chosen as the benchmarking process. The second step was to select companies to be benchmarked. In this thesis, external benchmarking companies are Metso Minerals and Sandvik Mining and Construction. One reason for choosing these two companies was the fact that they are both mechanical engineering companies like Cargotec. Secondly, both Cargotec and these two companies provide service solutions and spare parts for their global customer base. There were also past benchmarking cooperation and business contacts that made the negotiations and arrangements more straightforward. Furthermore, internal benchmarking was done as well, in order to get better understanding of Cargotec's service business and its needs. Internal benchmarking was exploited with Singaporean Cargotec CHS Asia Pacific Pte Ltd.

The third step was preparing questions for the benchmarking interview. The front line unit interview was used as an outline but it was modified to be suitable for the benchmarking. Only few topics were chosen to be investigated and compared. First objective was to get a short introduction of companies' spare part operations. After this interview focused on how benchmarking companies manage their inventory items, what kind of inventory management policies they have, and what KPIs and follow-up tools they use. The emphasis of the benchmarking interviews was on the stocking strategies in multi-echelon inventory system. The benchmarking interview outline can be seen from appendix 5.

5.1.1. Metso Minerals

Metso Minerals is one of the business areas of Metso Corporation. They are a global supplier of mining and minerals processing equipment and systems. Their main customer groups are mines and minerals processing plants, energy industry, engineering companies, and metal industry. Metso Minerals provides also service solutions for its customers. These include for instance spare and wear part contracts, equipment refurbishing, field services, and preventive maintenance.

The spare part network of Metso Minerals consists of various locations and echelons. In EMEA region, the main warehouse is in Benelux area and it is operated by an external service provider. Predetermined SKUs are stocked at this central warehouse and it also acts as a consolidation point for large volume purchase orders from their biggest suppliers. Thus many make-to-order parts, which are not stocked in Metso’s central warehouse, are routed via this hub. Besides the main warehouse, there are also various satellite warehouses in the EMEA region. Satellite warehouses order parts mainly from Belgium’s warehouse but they have also own, local suppliers. However, the main warehouse has the highest number of supply sources and largest volumes. The purpose of local warehouses is to serve local markets. For example, the local unit in Tampere supplies parts to Baltic countries. The local markets consist of various operators, such as local sales companies, dealers, and customer sites. Metso has also service location network which holds spare parts for daily consumption and preventive maintenance.

In the service network of Metso Minerals, spare part deliveries include three different order types. These are standard, express, and break-down orders. Standard orders are used for regular replenishment and express orders when the request is more urgent. Break-down order is the most urgent of the order types and it is used mainly in machine down situations. Orders are delivered mainly from the responsible front line unit but direct deliveries are possible as well. Equipment service jobs can be done either at the customer location or in Metso’s repair shop, depending on the type of equipment. All in all can it be said that the service network model is quite similar to the one used by Cargotec Services.

Metso Minerals have divided their spare parts into wear and spare parts. Wear parts are those which are in contact with rock when the machine is running. Thus other parts are spare parts. However, the actual item classification model is based on monetary usage and transaction quantity from past 12 months. The first segmentation is done by ABC-analysis which divides items into three segments. The second segmentation is done by application of XYZ-analysis which has four segments. The transaction activity determines whether or not items are stocked.

Inventory levels and replenishments are controlled segment-specifically with ROP and EOQ principles according to consumption history and forecast. Another used item classification factor is the item criticality. Part is classified as critical if the machine does not work without it. Critical parts are also relatively difficult to procure because they have scarce supplier base and the parts are often customized. For example wear parts are often moulded as per Metso’s own design. These components can be relatively difficult to procure and supply quickly to customer which is why using safety stocks is relevant in many cases. In summary, as presented in figure 5.1, inventory planning and segmentation are based on item transaction frequency, monetary usage, and item criticality. This policy is very similar to Cargotec Services’ spare part policy.

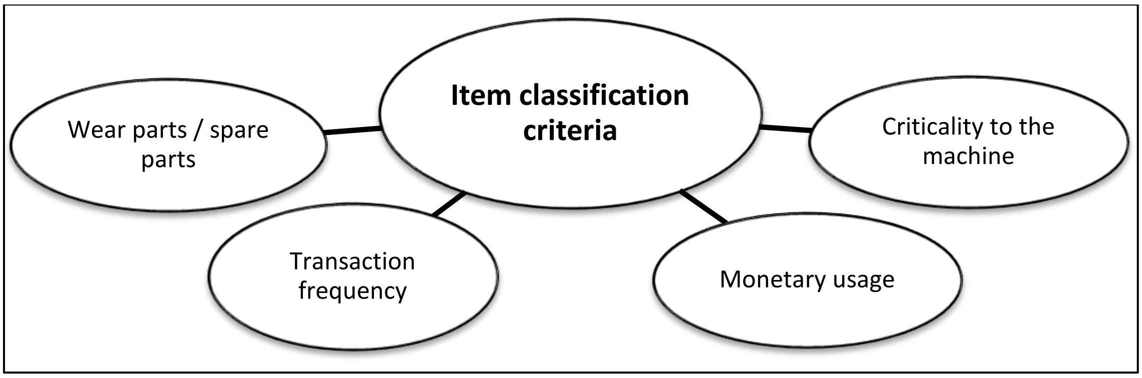

Figure 5.1. *Item classification criteria of Metso Minerals.*

Location-specific spare part assortments are determined by different factors. First of all, Metso Minerals has a spare part team that gives stocking recommendations for sales offices and largest customers. For instance when a new machine is sold to a major customer, spare part recommendation team is notified, and they will provide a spare part list for the customer. The list gives information about which spare parts the sold machine uses and which parts should be kept in stock. In the units of Metso Minerals, the main guideline is to stock only fast-moving and critical items at the local units. Other parts can be stocked in the central warehouse which has more extensive item assortment. Thus most of the non-critical, expensive, and other items with sporadic demand are pooled in the central warehouse.

Performance of inventory management is measured with different KPIs. Customer service KPIs include for example availability and delivery reliability. Availability describes how many of the order lines have been supplied directly from the warehouse. Respectively, delivery reliability indicates if orders have been delivered as per customer requirements, such as item type, quantity, and delivery date. Inventory and warehousing performance are measured as well. These measurements include such as average inventory value and inventory turnover.

5.1.2. Sandvik Mining and Construction

Sandvik Mining and Construction is a business area of the Sandvik Group. Sandvik Mining and Construction (SMC) is a global supplier of rock drilling, rock excavation, processing, demolition and bulk-materials handling equipment, technical solutions, and services. Services division of SMC consists of maintenance services and SMC Logistics which provides logistics services for the product lines of Sandvik. This benchmarking focuses on operations of SMC Logistics because it is responsible of after sales logistics, warehousing, and inventory management.

SMC Logistics purchases its spare parts from both external suppliers and SMC’s own assembly factories. External suppliers provide commercial parts and subcontracted parts that are produced according to SMC’s requirements. Conversely, special parts that need

SMC's core know-how are purchased internally from SMC's factories. SMC Logistics has currently four DCs which are located in Holland, USA, Singapore, and South Africa. Because most of the suppliers are located at Europe and North America, the DCs in Holland and USA function as consolidation points to other DCs and thus they basically form the highest DC level. There are hundreds of thousands of items in the information system but only predetermined items are kept in the DCs. One significant difference to Cargotec's network is that SMC Logistics' distribution network works mainly by direct deliveries. This means that customers make orders to their market area offices but the spare parts are delivered directly from the corresponding DC. Only invoicing is directed through the market area office. Thus there are only small inventories at the front line.

The inventory classification model of SMC Logistics is quite similar to Cargotec's classification. The classification criteria are transaction frequency and monetary usage. Transaction frequency is segmented into five classes which are known as sales intensity codes (SICs). Conversely, monetary usage is divided into three classes by percentage of COGS. These two criteria form the item classification matrix which is presented in figure 5.2.

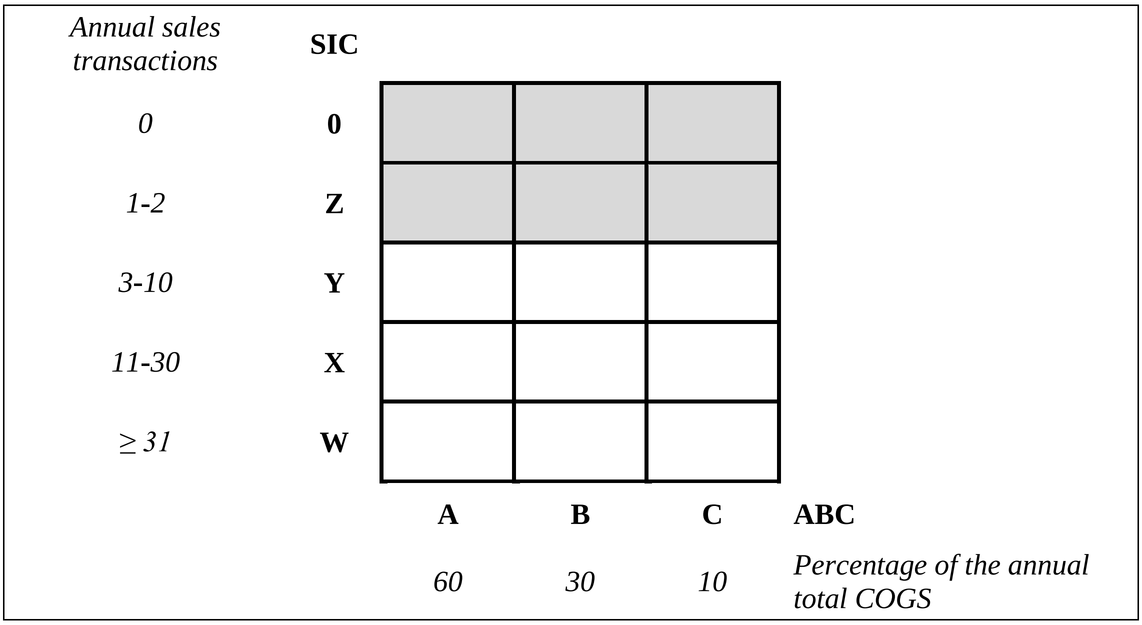

Figure 5.2. *Item classification matrix of SMC Logistics.*

At each DC, the items are divided into the classification matrix automatically once per month. Each segment of the matrix has its own service level target. The segments are also controlled by ROP, safety stock, and EOQ calculations. These are updated once per week. In the DCs, the guideline for stocking is that items in classes W, X, and Y are stocked. Hence, items with less than three annual sales transactions are not stocked without special request. The front line uses these same rules as well. In the future, the class Y might be divided into three smaller classes because number of SKUs in this class is increasing. This way SMC Logistics can define more specific assortment rules for their warehouses.

At the moment, items are not systematically classified in terms of criticality. However the special needs of front line markets are taken into account by holding strategic stock which is formed manually. First of all, the product lines provide machine-specific lists of spare part recommendations to the front line. This is done before the machines are released to the market. In this way, the front line gets information about what spare parts they should hold in the strategic stock in case of machine down situations. Front line will then make machine population based stocking requests to the planning and control organization which examines the requests and makes manual adjustments if necessary. Front line sales can also make strategic stock requests which are based on the interaction with the customers and customer requests.

Strategic stock requests can result from various alterations, such as adding new machines to the market, increasing or decreasing the existing machine population, upgrading or replacing spare parts, or changes in contract base. Planning and control organization, in consultation of regional inventory managers, is responsible for determining where the strategic stock will be located. The strategic stock requests should be analyzed critically because they are based on predictions and personal opinions, and because the number of Z-class SKUs tends to be relatively high at the front line. Planning and control organization is also responsible for reviewing the usage of strategic stock items on a monthly basis.

Inventory performance measuring is done with a collection report. This report shows for instance warehouse specific order line fill rates. These are calculated by comparing ordered lines and their contents to the available inventory. Thus it shows the proportion of lines that are filled promptly and completely from the stock. Another indicator is inventory coverage which shows how many pieces of the ordered amount in lines are available. In addition, SMC Logistics can also see from their system if orders are delivered to the customer on time. This is possible because they have integrated their system to the systems of their main haulers. Conversely, inventory movement is measured mainly by days in stock which is basically the inverse of inventory turnover. It describes how many days the items are in stock on average. SMC Logistics measures also total value of different item segments of the classification matrix. Proportion and value depreciation of slow-moving and obsolete inventory is monitored as well.

Majority of SMC’s after sales are in the same ERP-system. This enables information transparency and centralized inventory planning in SMC Logistics’ supply chain. Transparency is currently being increased for example by collecting information from suppliers when delivery dates of purchase orders change. This information can be vital when servicing the customer, which is why the alterations in expected delivery dates are made visible all the way to the front line sales.

5.2. Internal benchmarking

The internal benchmarking was done with Cargotec CHS Asia Pacific Pte Ltd (referred as Cargotec CHS from now on) which is located in Singapore. This benchmarking differs slightly from the external benchmarking as it was mainly done in order to get more comprehensive view of Cargotec's service business. The interview was done by e-mail and the questions in appendix 4 were used as interview outline.

Cargotec CHS is a stock hub for front line operations of Asia Pacific (APAC) region. The main hub is located in Singapore and its satellite warehouses in various front line markets. Its end customers are main companies at industrial, waste handling, construction, port, terminal, and marine operations. The most important customers are port and marine operators who provide largest share of revenue and profit. Cargotec CHS's customers have contracts mainly for equipment maintenance service and spare part supply. The required service level and response time are determined and influenced by industrial norms and competition in the market. Service level is influenced also by customer's buying habit. The buying habit is an important factor when considering the cost and investment on the service level because the targeted service level depends on customer's willingness to pay for those services.

Cargotec CHS classifies items by customer types and their buying habits. In general, items are classified according to transaction frequency and item criticality. Criticality is basically determined by item's impact on the key function of equipment. The degree it impairs the equipment's functionality defines the level of criticality. Lead time effects on the criticality as well. Item with a relatively short lead time is less critical than item with a longer lead time. The used item classification model is the basis for inventory management. In general, stock levels are planned for different segments by adjusting the desirable parameters set in the inventory management program. This program processes the historical sales data and provides optimal stock assortment.

Cargotec CHS measures performance of inventory management monthly by first pick rate, completeness, inventory turnover, and obsolescence rate. First pick rate measures the available stock in contrast to the ordered lines and completeness measures the promptness in completing orders according to agreed delivery dates. Inventory turnovers are measured in order to evaluate inventory movement and secondly, to compare the inventory cost to the provided service level. Obsolescence rate measures the amount of obsolescent inventory and thus the accuracy of their inventory planning.

According to Cargotec CHS, Central Operations could support their operations by visiting their office more often and thus attaining better understanding of the market and environment. They state also that sharing information and experiences between Central Operations and other front line markets would be useful. Furthermore, Cargotec CHS requests also possible assistance from Central Operations for improving their performance. Cargotec Services should strive for solution that is managed centrally and has higher volumes but is well organized and synchronized. Implementation of intelligent system, which is flexible in terms of market dynamics, would be good for the service business. According to Cargotec CHS, better engagement of customers to the business is vital because they are the closest to the equipment and decide what services they want to buy.

6. RESULTS AND DISCUSSION

6.1. Inventory streamlining process

As stated before, supply chains should be examined from the perspective of entire system that supplies the parts to end customer. It is not reasonable to strive for individual inventory management optimization but to optimization of the whole supply chain. Thus Cargotec Services should implement consistent inventory management policy and plan inventories of Central Operations and front line from system perspective. Implementing systematic inventory management policies also in front line units enables for example lower inventory levels and higher inventory turnover which results in lower inventory carrying costs.

Inventories of front line units tie up approximately x of the total inventory value of Cargotec Services. Thus streamlining of the inventories has significant cost reduction potential if central stocking is stressed over local stocking. Some of the items, such as critical and highly active parts, cannot be stocked solely in the DCs but for instance slow-moving and expensive items could be stocked centrally instead of multiple locations. Central stocking should be stressed especially in Central Europe where front line units are situated close to EDC. In urgent cases, these front line units can be reached from EDC in a matter of hours. Moreover, obsolescence risk is much higher at front lines because the local demand is lower compared to global demand. This is why locally stocked items become more easily non-moving inventory. Although locally non-moving and globally active parts can be returned to central warehouses, the value of items can depreciate and it is more rational to prevent these situations beforehand.

Thus the inventory management process of Cargotec Services should be streamlined and inventory management policies unified. The purpose of the streamlining process is to improve information transparency, optimize total inventory value, and increase inventory movement while ensuring suitable service level in the supply chain. The basic idea of the streamlining process is to examine front line unit’s inventory and inventory management process, and try to develop and systematize inventory management. This includes item activity analysis and examination of where different item groups should be stocked. The purpose is also to standardize inventory management policies between Central Operations and front line units.

Before the actual streamlining analysis can be done, Central Operations should investigate the front line’s operations. This includes for example examination of front line’s service business, service network structure, and basic operations. It is also important to find out what kind of customers and service contracts they have in order to understand what the basic requirements of inventory management are. The preliminary front line investigation can be done according to the outline presented in appendix 4.

When front line's operations have been introduced to Central Operations' representatives, the streamlining process can move on to the analysis stage which consists of various steps. The steps include data collection and preparation, transaction and activity analysis, stocking location analysis, stock return analysis, and proposing new inventory structure. The complete process can be seen from figure 6.1.

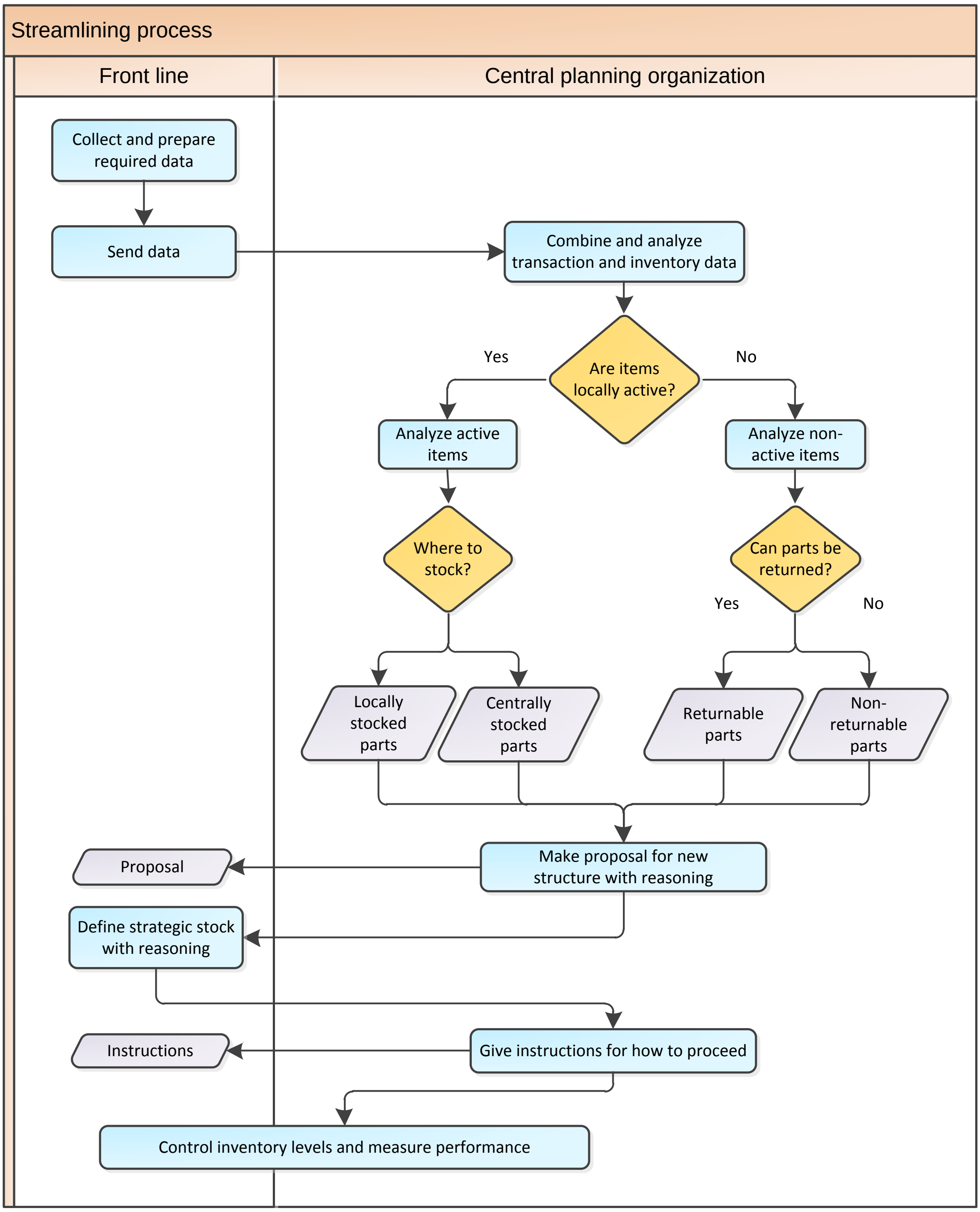

Figure 6.1. *Steps of the streamlining process.*

The first step is to collect data from the front line. This data is will be used when determining item activity, inventory assortments for different echelons, and return suitability. The required data is first output from the front line's information system by front line personnel. The data should be in prepared and cleaned if necessary and saved into Excel format. Then these files should be sent to the central planning organization. Table 6.1 shows what information the files should include.

Table 6.1. *Data to be collected from the front line.*

Inventory data	Inbound and outbound transaction data (24 months)
• Part number (item code) • Part description • Quantity on hands • Unit cost price • Name of supplier • Supplier code • Last transaction date • Warehouse (in case of multiple warehouse locations)	• Invoice number • Transaction date • Part number (item code) • Part description • Customer number and name • Transaction type • Invoiced quantity (sales or return) • Unit and total cost price • Unit and total sales price • Warehouse (in case of multiple warehouse locations)

6.2. Item activity analysis

In item activity analysis, the main objective is to determine which parts are locally active and which are not. This is done by analyzing local inventory and transaction data. After activity analysis, a global stocking strategy needs to be determined for locally active items. Conversely, the group of non-active items needs to be divided into returnable and non-returnable items. This analysis and the included decisions, which are also illustrated in figure 6.2, will be done by central planning organization.

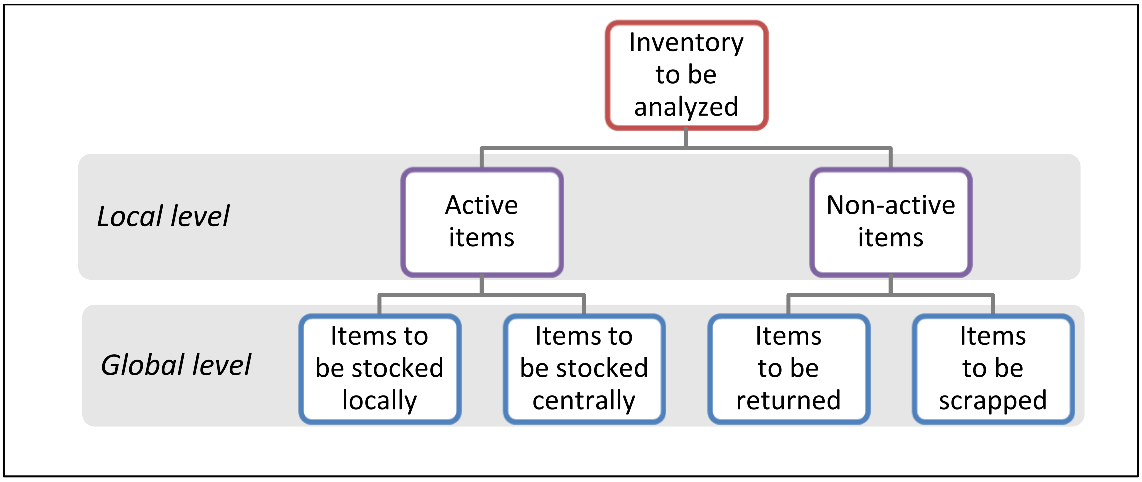

Figure 6.2. *Different item groups of the item activity analysis.*

The item activity analysis begins when inventory data and outbound transaction data are received from the front line. The transaction frequency will be the basis for determining item activity. Some problems arose when gathering the inventory and transaction history data from the example front line unit. Because they had implemented SAP only recently, the system did not have enough history data. On the other hand, the old system had already been disabled and the output data was limited. Because of these facts, required data could not be gathered at the moment. Thus an alternative data source had to be chosen in order to form an example transaction analysis. Fortunately, suitable data was received during the thesis from another front line unit.

Before the actual activity analysis, the received transaction data must be examined and filtered. The data should include only outbound transactions of spare part sales and spare parts consumed in service jobs. Thus all other transactions, such as labor, rental, delivery, and maintenance charges, must be filtered out. After this, the data is assorted by transactions frequency, that is, how many times each item has been sold during the review period. The activity analysis will be carried out with both period of 12 months and period of 24 months. The main focus is on the past 12 months but the longer period is analyzed in order to identify obsolescent items.

When dividing inventory into active and non-active segments, the criterion is sales transaction frequency. If an item has been sold at least one time during 12 months, it is counted as active. Conversely, items without sales transactions are counted as non-active items. When the transaction data is analyzed, it is combined with the inventory data. In the example inventory data, there are altogether x registered items which include x items with on hand stock and x items without on hand stock. x of the on hand items are active and x are non-active. The results of the activity analysis are presented in figure 6.3.

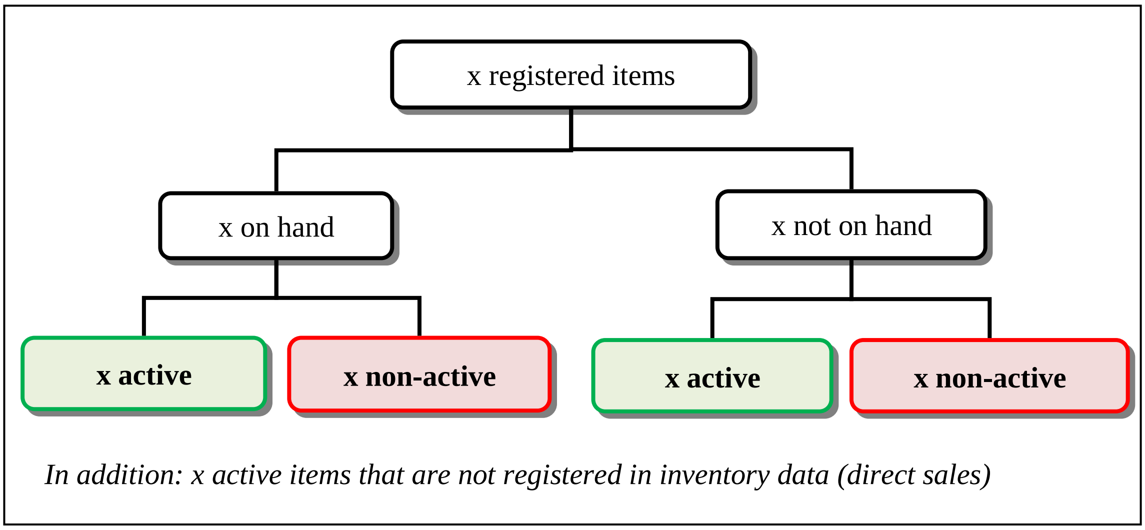

Figure 6.3. *Results of activity analysis.*

The active items must be further analyzed in terms of suitable stocking location. This analysis is presented in chapter 6.2.1. Conversely, the non-active items should not be stocked at the front line. Thus these items are analyzed in terms of return suitability. This examination is presented in chapter 6.2.2.

6.2.1. Active items

In order to enhance item flow, item activity, and inventory turnover while preventing obsolescent and excessive inventory in the supply chain, a common stocking policy must be determined for Cargotec Services' multi-echelon inventory system. This refers to the dilemma which active part segments should be stocked on local echelon and which on central echelon, and what are the rules when making these decisions. The new principle for determining stocking location, which is presented next, is based on the ABC-XYZ-classification, the eight-dimensional stocking strategy presented by Botter and Fortuin (2000), and the classification methods presented in chapter 3.4.3. When determining stocking location, the first decision making criterion is the demand pattern which can be seen from the sales history data. The sales history data from past 12 months is examined in terms of local demand frequency and COGS. Items are then divided into segments based on these two factors. Items are then stocked centrally or also at local level, depending on which segment they end up. The general principle of determining stocking location can be seen from figure 6.4.

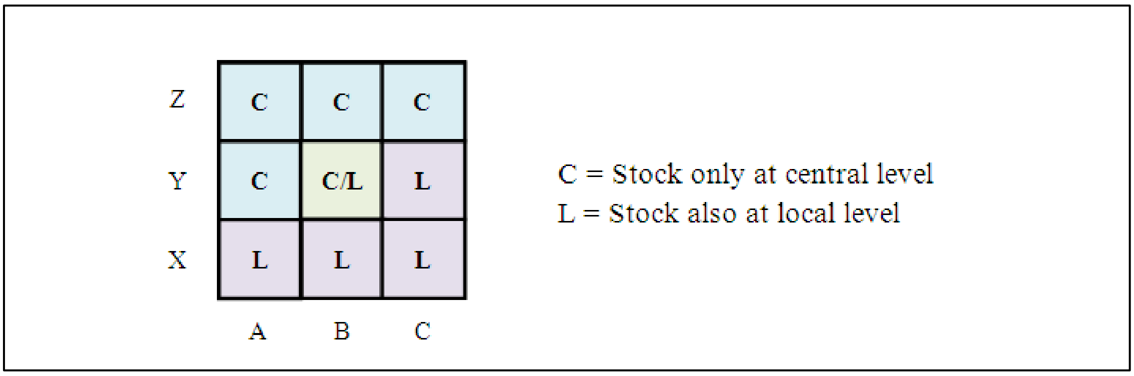

Figure 6.4. *General principle for determining stocking location.*

The four item groups marked with C should be stocked only at the central level. Items in class Z1 are sold relatively infrequently which is why they should be stocked at central level in order to prevent obsolescence. Items in class A/Y are sold more frequently but they tie up capital into the inventory which is why central stocking is still better option. The segment with marking C/L needs further examination by taking item prices into consideration. Low-price items can be stocked at the front line whereas high-price items should only be stocked centrally.

Items in L-groups should be stocked also at the front line. Because locally active items are also active at the central level, locally stocked parts will be stocked also at the central level. Partly because of this, local inventory levels should be kept lower than in Central Operations. Basically, local inventories should be planned to fulfill daily or weekly demand whereas central inventory fulfills monthly or annual demand. Thus the inventory turnover targets are higher at the local level and the turnover targets should be defined separately for each segment of the matrix.

In order to determine suitable limits for transaction frequency classes, sales frequency-specific results must be examined. The analysis is done in terms of best possible service level that can be achieved by stocking items which have a certain transaction frequency. For example, if the front line unit keeps every item that has been sold even once in past 12 months, then the inventory would cover every demand projected from the history and the theoretical service level would be 100 percent. But of course, this kind of decision is unreasonable in terms of invested capital. The summary of this examination is presented in table 6.2. The first column indicates the transaction frequency level from the sales of past 12 months. The next four columns present the cumulative results in euros and the last four present the cumulative results in percentages. The cumulative values are counted by adding the frequency-specific value of a higher cell into the lower one. More precise results of the 12-month activity analysis can be found from appendix 6.

Table 6.2. *Summary of transaction data analysis.*

Freq	Items	Trans-actions	Sales volume (MEUR)	COGS (MEUR)	Items	Trans-actions	Sales volume	COGS
1	x	x	x	x	**x %**	**x %**	**x %**	**x %**
2	x	x	x	x	**x %**	**x %**	**x %**	**x %**
3	x	x	x	x	**x %**	**x %**	**x %**	**x %**
4	x	x	x	x	**x %**	**x %**	**x %**	**x %**
5	x	x	x	x	**x %**	**x %**	**x %**	**x %**
6	x	x	x	x	**x %**	**x %**	**x %**	**x %**
7	x	x	x	x	**x %**	**x %**	**x %**	**x %**
8	x	x	x	x	**x %**	**x %**	**x %**	**x %**
9	x	x	x	x	**x %**	**x %**	**x %**	**x %**
10	x	x	x	x	**x %**	**x %**	**x %**	**x %**
11	x	x	x	x	**x %**	**x %**	**x %**	**x %**
12	x	x	x	x	**x %**	**x %**	**x %**	**x %**
13	x	x	x	x	**x %**	**x %**	**x %**	**x %**
14	x	x	x	x	**x %**	**x %**	**x %**	**x %**
15	x	x	x	x	**x %**	**x %**	**x %**	**x %**

As the results show, x percent of the sales volume and x percent of the transactions are caused by the items which have been sold at least 15 times per 12 months. However, this item group includes only x percent of all different items sold. Respectively, x percent of the sold items have been sold only once or twice in 12 months and these items generate just x percent of the sales volume and x percent of the transactions. This is a typical situation in spare part business that complicates for example the planning of inventory assortment and forecasting the demand. In order to streamline the inventory management and activate inventories, the parts with sales frequency of 0, 1, or 2 should not be stocked without special reason. This is also the policy of Central Operations. In addition, because the case front line unit is located close to EDC, also the next few frequency levels are too inactive to be kept at the front line warehouse. These items should be stocked only centrally.

The results of activity analysis were examined in consultation with the management of central planning organization. In this example front line analysis, the resolution was to create 5 different segments in terms of transaction frequency. The segments and set activity limits can be seen from table 6.3.

Table 6.3. *XYZ-classification limits.*

Class	**X**	**Y**	**Z1**	**Z2**	**N**
Transactions (order lines) per 12 months	≥ 12	6-11	3-5	1-2	0

This means that when these limits are reflected to the previously presented general principle, items that have under 6 transactions per 12 months should not be stocked at the front line. Frequency of 6 transactions per 12 months corresponds sales activity of approximately once in every second month. In this example analysis, the lower frequency levels can be considered as locally non-moving or slow-moving inventory which ties up excess capital compared to sales volume per item. Thus this part of the inventory needs to be examined separately in terms of return suitability.

Respectively, the ABC-analysis of on hand inventory will be carried out with the 12-month transaction data by using the same limiting values than in the parts policy of Central Operations. Thus the first 80 percent of total COGS will form the class A, next 15 percent the class B, and last 5 percent the class C. The class D includes only items that have not been sold during past 12 months.

When XYZ- and ABC-classifications are done, the inventory can be divided into the classification matrix. The results of the partition can be seen from figure 6.5. The first number in a cell indicates how many on hand items each segment contains and the second number present the division of items in the complete 12-month transaction data. More specific results are presented in appendix 8.

0	**N**	x (x) **C**			
1-2	**Z2**	x (x) **C**	x (x) **C**	x (x) **C**	
3-5	**Z1**	x (x) **C**	x (x) **C**	x (x) **C**	
6-11	**Y**	x (x) **C/L**	x (x) **C/L**	x (x) **L**	
≥ 12	**X**	x (x) **L**	x (x) **L**	x (x) **L**	
		A	**B**	**C**	**D**
		80	*15*	*5*	*0*

Figure 6.5. *Segmentation of front line's on hand inventory.*

In the previous segmentation, class N includes only non-active items. These are further analyzed in chapter 6.2.2. Classes Z2 and Z1 consist of items that should not be stocked at front line without special reason. Thus all segments that have letter C should be stocked only centrally and returned to Central Operations if they fill the return requirements which are presented in chapter 6.2.2. How non-returnable items in classes Z2 and Z1 are treated, will be determined case-specifically by Services management.

Classes A/Y and B/Y should be further analyzed in terms of item price. In this example analysis, all items in class B/Y have cost price of less than x euros. Thus all of these items can be stocked locally. Class A/Y consists mainly of low-cost items as well but there are also x items that have a cost price of more than x euros. These items should be reviewed by local service organization and the items should be stocked locally only if it is compulsory. However, classes C/Y and X should be stocked at the front line because they include only fast-moving and relatively low-priced items.

This framework is based on the fact that the case front line unit is located relatively close to EDC. Because of this, locally slow-moving items can be delivered from EDC during same day if the demand is extremely urgent. Also next morning courier deliveries are possible. In case of more distant front line units, the stocking location decisions must be investigated more carefully.

The stocking model presented above is not all-inclusive, because it is based only on history data and mathematical calculations. Thus, the model does not take into account changes in future demand estimations, machine base, or front line's special requirements such as service contract agreements. Because service level and response time are the most important competitive factors in Cargotec's service business, manual stocking should be enabled. This means that the knowledge of front line personnel, machine sales, and product support needs to be exploited by enhancing communication and enabling a way to make strategic stocking requests.

To begin with, machine sales and product support should communicate information about new machine sales, model modifications, and spare part needs of the machines. On the other hand, front line units need to document the machine base and contracts of their service business in more standardized and structured manner. This kind of information transparency and communication is the basis for efficient and systematic inventory planning and control in multi-echelon inventory system. The front line should also have the possibility to request manual stocking of strategic items. The communication and strategic stock request process between product support, front line units, and Central Operations can be done with the SharePoint collaboration tool. Thus, the utilization of SharePoint should be extended in future.

The definition of item criticality must be redefined when planning the strategic stock in multi-echelon network. In terms of stocking location, the valuation of item criticality should be based mainly on the time, in which the failure should be corrected. In this case the most important factor is how much time there is to react to the spare part demand and that determines the stocking level. The available reaction time depends on the consequences which result from failure situation and inventory shortage. This means that if Cargotec must provide the spare part to customer on the same day, the spare part needs to be stocked in the front line warehouse. Respectively, if same day supply is not imperative, central stocking is adequate in terms of criticality. Thus, when SAP is fully implemented together with Servigistics, location-specific criticality and steering parameter modifications must be enabled in the inventory management system. On the other hand, when determining which parts are critical at the central level, the decisions should be based on purchase lead time, availability risk, level of part's technical specificity and customization, and also the importance to machine's functionality.

When forming local or central strategic stock, the requesting party must communicate the reasons for stocking to the party that makes the analyses and decisions. This means that the requester must provide information about which items, where, why, and how long stocking would last. With this information, the strategic stock can be planned more accurately. When requests are created, the decision-making party must analyze them also in terms of invested capital. Because the strategic stock ties up capital in inventory, the item cost price is a relevant factor. For instance very expensive parts should not be stocked at the front line. Because of this, a common guideline for item price was determined. According to it, items with cost price of x euros or more should not be stocked at the front line. This guideline and secondly, whose balance sheet the investment will be positioned on, should be the criteria for determining who analyses the requests and who can make the final stocking decision. Basic rule is that local strategic stock must be analyzed by local organization and central strategic stock by central organization. Table 6.4 presents the guidelines for requesting and forming strategic stock.

Table 6.4. *Guidelines for requesting strategic stock.*

Requests for local strategic stock			
Item cost price	Analysis by	Final approval by	Details
< x €	Local services organization	Central planning organization	-
x - x €	Local services organization	Management of central planning	-
> x €	No local stocking		
Requests for central strategic stock			
Item cost price	Analysis by	Final approval by	Details
< x €	Central planning organization	Central planning organization	-
x - x €	Central planning organization	STS manager together with central planning management	The management must be consulted when making stocking decision
x - x €	Central planning organization	Director of Parts and Logistics	The management must be notified about the stocking decisions
> x €	Central planning organization	Vice President of Parts and Logistics	A written request (documentation) must be provided to the management

When the active front line inventory is analyzed, some further actions must to be done. First of all, there are items that will be stocked only centrally but are currently located at the front line. One option is to return these parts to the DC. This could be done in the same way as the normal return process, which is described in chapter 6.2.2, but in this case the credited amount would be x percent of sales office’s present purchase price, and the return expenses would be paid by Central Operations. Another way to handle the process would be by adjusting inventory steering parameters so that inventories of selected items would cease automatically in the course of time and drop from the local assortment. However, this decision will be done separately by Cargotec Services management and thus it will be excluded from this study.

6.2.2. Non-active items

Locally non-active items should not be stocked at the front line. In order to activate inventories in the multi-echelon system, parts that are not recently added and have not had sales during last 12 months should be delivered back to the DC. Return process begins from the previously presented item activity analysis. After items are divided into locally active and non-active items, central planning organization will analyze which of the non-active items can be returned to the DC. When the analysis is done a return proposal will be sent to the sales office. Return proposal will be reviewed by local service organization and they will determine which items are not critical for their operations. Non-critical and returnable items will then be returned to DC.

Non-active items can be returned to Central Operations if they meet the return requirements. Return shipment to Central Operations will be approved only if

- parts are still in resalable condition
- parts are not damaged or rusty (rust protection must be used if there is a risk)
- parts have not been mounted into a machine
- return includes correct amount of items as informed in the return proposal
- all items are complete (no missing components)
- all items are marked clearly (but not on the surface of parts)
- original packing or sealing is unbroken
- part unit value is higher than x € or total line value is higher than x €
- and the total value of the return shipment is over x € (after return fee deduction).

If these return requirements are met, Central Operations can approve the return shipment. However, internal part return policy includes also definition for non-returnable part types. According to the policy, part types presented in table 6.5 are always non-returnable and will be refused by Central Operations.

Table 6.5. *Non-returnable part types.*

Part type	**Additional information**
Programmed parts	Components that have customer specific programming
Superseded parts	Items that have been superseded by new items
Phantom parts	Items that consist of other items
Rubber parts	Such as seals, O-rings, gaskets, and hoses
Kits	For example repair, filter, and seal kits
Filters and hydraulic pipes	-
Unknown parts	Items that are not purchased from Central Operations
Non-stocking parts	Items that are not active globally at Central Operations

Approved and properly returned parts will be credited to the returning party according to their present purchasing price. Return fee for parts, which have been purchased during previous 24 months, is x percent of the present purchasing price. Thus for these parts, the credited amount will be x percent of the present purchase price. On the other hand, parts that have been purchased before the previous 24 months are not credited at all. Reason for this is the fact that parts with no transactions from past two years should have been written off by now and giving credit for parts that have no longer value is not acceptable. Returning party is obliged to arrange transportation for the return shipment and pay the expenses for creditable parts. Older, non-creditable parts can currently be returned at Central Operations' expense. This option has been introduced in order to motivate front line to return also these parts.

If the returned parts do not meet the return guidelines, the return will be rejected. In this case, the parts will be scrapped and additional scrapping cost fee of x euros per part will be reduced from the credit amount. The returning party is also responsible of the sufficient packaging of the return shipment. Thus if parts are damaged during transportation, Central Operations is not obliged to credit the returned parts.

Also procedures for parts, which are both non-returnable and locally non-active, need to be determined. There are three ways to handle this type of inventory. The first one is to eliminate these parts, which have been written off in bookkeeping, completely by scrapping them. In the two other possibilities storing of the parts is continued either internally or externally at the front line. In internal stocking, the non-active inventory is stocked centrally in one predetermined storage location of the front line. Conversely, external stocking refers to stocking the parts at a third party service provider. Thus in these latter cases the parts are not eliminated permanently. The most suitable procedure needs to be defined case by case.

The guidelines, which were presented above, should be followed when examining the locally non-active parts. The examination was done for the example data as well but without the actual inspection of items. In the example case of this thesis, the partition to returnable and non-returnable parts would be as shown in table 6.6.

Table 6.6. *Returnable and non-returnable items (locally non-active).*

	Returnable	**Non-returnable**	**Total**
Items	x	x	x
Inventory value (at item cost price)	x €	x €	x €

6.2.3. Summary of the front line inventory analysis

The complete results of the activity analysis can be seen from appendices 6, 7, 8, and 9. Figure 6.6 presents how on hand inventory is divided into different inventory groups based on 12-month activity. First of all, the figure presents the amounts of active and non-active items. It shows also how many of the non-active items are returnable and how many are non-returnable. Conversely, active items are divided into locally stocked and centrally stocked items. There were x items that should be stocked locally when considering transaction history. Remaining x items should be stocked centrally if the items are globally active. As mentioned before, the return procedure of local items, which should be stocked centrally in future, is determined later by management of Cargotec Services.

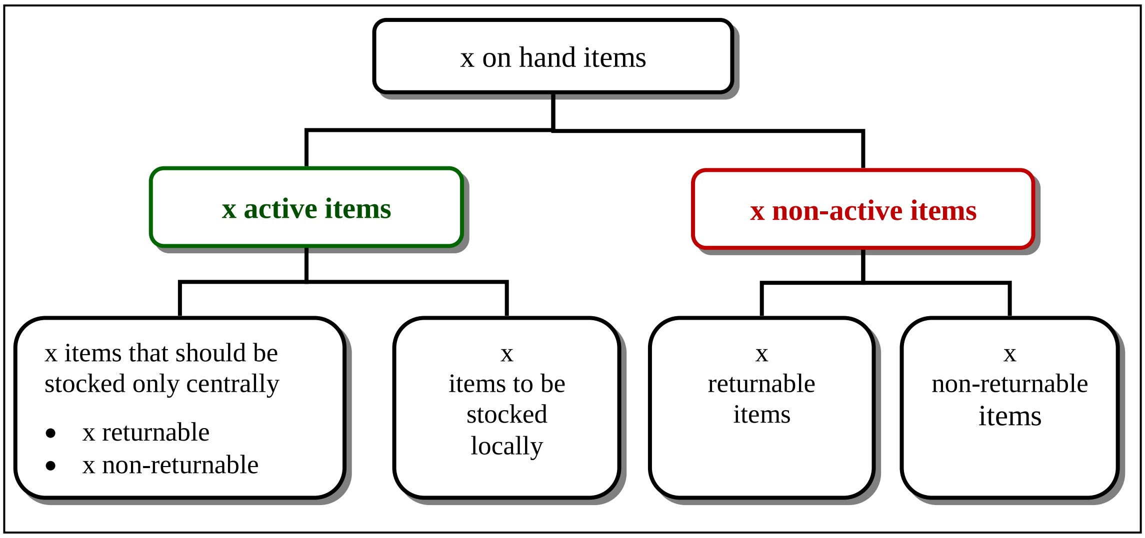

Figure 6.6. *Summary of the on hand inventory analysis.*

Table 6.7 presents the main results of the inventory analysis in terms of inventory activity and value at cost price. As the table shows, x percent of the on hand items, and x percent of the inventory value is totally obsolescent, that is, this part of the inventory has not been sold during past 24 months. The corresponding percentages for 12-month review period are x and x. Non-moving inventory should be returned to Central Operations, scrapped, or handled otherwise if there is no strategic reason for the local stocking.

Table 6.7. *Summary of the local inventory and transaction data.*

On hand inventory:				
	Non-active (0 transactions)		Active (≥ 1 transactions)	
	Share of item assortment	Share of the inventory value	Share of item assortment	Share of the inventory value
Past 12 months	x %	x %	x %	x %
Past 24 months	x %	x %	x %	x %

Complete outbound transaction data:						
	1-5 transactions			≥ 6 transactions		
	Share of items	Share of transactions	Share of sales volume	Share of items	Share of transactions	Share of sales volume
Past 12 months	x %	x %	x %	x %	x %	x %

The value of obsolescent on hand inventory is approximately x euros at the cost price. Only x percent of the value of obsolescent inventory could be returned to DC while x percent of the inventory value should be scrapped. However, either way the front line inventory value could be decreased by x euros which correspond x percent of the current total value. Respectively, the value of slow-moving on hand inventory is approximately x euros. Because these items are still salable at the front line market, the most practical option would be to recalculate and adjust the inventory steering parameters and sell out all of the pieces in the warehouse. This way return shipment would not be needed. All in all, an inventory value reduction of over x MEUR could be done in the example front line unit in the long run. However, this figure does not include the effect of strategic stock determination which most likely decreases the amount of reducible inventory. In addition, in order to be able to define the total savings and effects of the streamlining, all front line inventories need to be analyzed and implemented to the central planning.

In addition, the example inventory data included x items, which have been sold during past 12 months, but which do not have on hand stock. Most of the items were sold only infrequently but x of them had over 5 transactions during past 12 months. Thus these x items should have stock at the front line unit according to the proposed stocking policy. There were also x sold items that were not registered in the inventory data. x of these items had over 5 transactions in 12 months but they created only around x euros of sales volume. Thus these items are not relatively important for the front line’s service business.

As mentioned before, all locally non-active items are not necessarily dead inventory. The locally non-active parts may include new and strategic parts that have been added to the assortment only recently. Some of these items are needed at the front line assortment for example because of a service contract. These items need to be identified by local service organization. Thus when a return proposal is given by central planning organization, the local service organization should examine the locally non-active and slow-moving item groups and define which items are critical to their operations. Strategic stock can also be requested as per the policy presented in table 6.4. In addition, the example analysis presented in this study was carried out with inventory data which consisted of momentary stock levels. Because of this some items, which had a stock-out at the moment, might normally have on hand stock. Thus the example analysis did not necessarily include the entire regular on hand inventory.

Besides the determination of which items to stock and on which level, regional service organizations should implement the principles of systematic replenishment and stock level control which are described in this thesis. These principles, such as ROP, safety stock, and EOQ calculations, need to be implemented in their spare part operations. They should also implement the ABC-XYZ-classification and segment-based service level targets. In addition, front line spare part management must implement systematic means for measuring the performance of their inventory management. This is explained more precisely in the next chapter.

6.3. Performance measurement

The interview of the case front line unit showed that front line inventory management does not have sufficient performance measurements, at least in this case. Thus it is necessary to investigate also the other front line units and establish common performance measurement guidelines. These guidelines and related instructions must be communicated to the front line. The guidelines should be established for measuring some basic inventory management KPIs. In terms of inventory planning and customer service performance, the key aspects of spare part operations are customer service level, inventory movement, and capital invested in the inventory. Thus these three areas need to be closely observed. Besides the market area-specific measurement, also wider review is needed. In order to be able to evaluate the total results of the streamlining, measurement should be done in terms of overall performance in the multi-echelon system. Thus the KPIs presented in this chapter should be examined also from the perspective of the whole supply chain. Another aspect that needs to be taken into account when using these KPIs, is that they can influence on eachothers results. Thus too high target on one KPI can result in unacceptable level on another KPI.

Service level is currently measured only at the supply point between Central Operations and front line. It is important to monitor also the real customer service level which is measured at the point of delivery to the actual customer. One way to measure service level is the order line fill rate, which is also known as availability, from the front line inventory. This is calculated as follows:

$$Availability = \frac{Order\ lines\ delivered\ promptly\ from\ stock}{Total\ number\ of\ order\ lines} * 100\%$$

Availability should be measured by total figure and separately for different item classes. However, this KPI does not reveal if orders are not delivered to the customer on time or if they have incorrect contents. These are important factors for customer service which is why these need to be monitored as well, for example by OTIF-rate presented in chapter 3.6.1. However, this kind of service level measuring requires for example seamless information sharing with the logistics service provider which can be challenging. Customer service is influenced also by performance of operational warehousing. Thus performance of operational warehousing must be measured as well. Transportation and operational warehousing related aspects are not in the focus of this thesis which is why the final KPIs must be determined separately for these aspects.

Efficiency of inventory management and planning accuracy consist of various factors. First of all, front line units should measure total inventory value on a monthly basis.

This is a simple way for monitoring tied capital. It is also important to monitor the value of non-moving inventory in proportion to the total value of inventory. Front line units should also implement another measurement of inventory activity. This can be done by inventory turnover rate which is calculated as follows:

$$Inventory\ turnover = \frac{Annual\ sales\ at\ cost\ price}{Average\ inventory\ at\ cost\ price}$$

Central Operations and front line units should implement different turnover targets for different item classes. The turnover target should increase when moving from C-class to A-class, and also when moving from X-class to Z-class. This is illustrated in figure 6.7. Spare part management should determine inventory turnover targets case by case. Basic rule is that front line inventory should fulfill daily and weekly demand, while central stock is planned to fulfill monthly or annual demand.

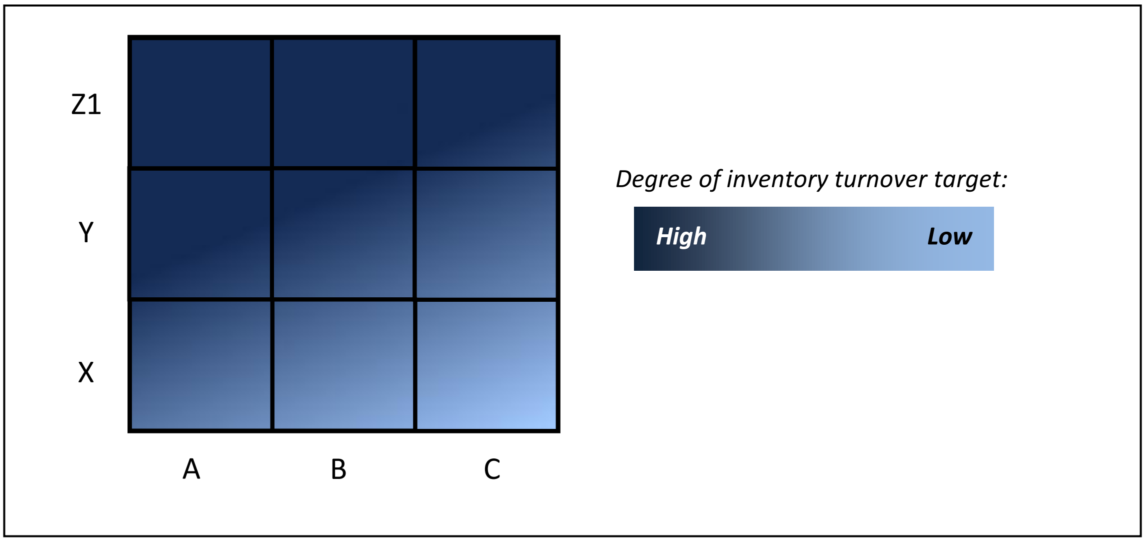

Figure 6.7. *Principle for determining turnover targets.*

Another aspect, which needs to be monitored, is the manually formed strategic stock. The responsible parties must review strategic stocks on a regular basis. Local strategic stock should be reviewed by local service organization and central strategic stock by central planning organization. Strategic stock should be followed up by monthly summary reports that include information about total number of strategic items, number of items added during the previous reporting period, and total value of the previous two. Responsible organizations should also follow-up strategic stocks in terms of activity.

7. CONCLUSIONS

7.1. Main results and recommendations

The most essential result of this thesis is the streamlining framework which provides the guidelines for examining the front line inventories. First of all, this framework includes description for how to carry out inventory activity analysis. Another main part of the streamlining framework is the policy for deciding stocking location for locally active items. This policy includes also instructions for the process of forming strategic stock in the service network. The inventory assortment related guidelines and classification were based on item transaction frequency, COGS, item cost price, and criticality. On the other hand, instructions were determined also for the non-active item group which is divided into returnable and non-returnable items. In addition, this thesis provides performance measurement guidelines which should be applied in inventory management. These results should be the basis for Cargotec Services' spare part operations in future.

Another purpose of the thesis was to compile essential inventory management related theory and unify inventory management policies between Central Operations and front line units of Cargotec Services. This thesis represents the basics of inventory management theory and inventory management policies of Central Operations. The thesis can be distributed as educational material and exploited when implementing common inventory management policies at Cargotec Services.

The example inventory analysis showed that remarkable share of the front line unit's inventory is non-moving or slow-moving. Thus the action proposal was to return returnable obsolescent items, scrap non-returnable obsolescent items, and sell out slow-moving items by adjusting inventory steering parameters. If this action proposal is fulfilled, Central Operations must ensure that the spare part replenishments to the front line will be delivered effectively and accurately in future. Because customer service level is significant competitive factor critical parts must be provided by the Central Operations with short lead times. In addition, when implementing the streamlining project, it is also extremely important to achieve central and local management's commitment to the project and its objectives. Without management's commitment and visible support, the changes cannot be implemented in the network.

This study included also benchmarking research. As the benchmarking showed, the inventory management policies, such as item classification and inventory control methods, are quite similar between Cargotec and the benchmarked companies. However there were some differences in used methods which were evaluated when establishing the streamlining framework. Added to this, SMC has higher level of information transparency which should be pursued by Cargotec. Their method of direct deliveries should also be considered as well. When promoting direct deliveries to customers from the DCs, front line inventories could be decreased. However, some of the differences in companies' way of actions result from the fact that the machine population, service businesses, and service networks differ between the companies. Thus all noticed differences and improvement possibilities cannot be utilized at Cargotec.

As mentioned before, information transparency is crucial in efficient supply chain management. Thus in future, high level of information sharing and cooperation has to be assured at least between Cargotec's own sales offices and Central Operations. Cooperation should be done with product support and machine sales as well. As the data gathering phase of this study showed, the current multiform information system base limits visibility between different units. In addition, interviewees of the front line stated that they do not get enough information about product and spare part modifications or what happens elsewhere in the corporation. SAP implementation, which is currently in progress globally, is one step towards better flow of information. SMC's information system is a good example of efficient information sharing. They have majority of the units in same system which enables better information transparency and flexibility. This enables forwarding of information from the suppliers to the front line for instance in cases where lead times and delivery dates change. This kind of supply information can be crucial for the front line sales in terms of customer satisfaction.

In addition, units of Cargotec Services should share experiences and information about common ways of working and for example product updates. Inventory parameters and product support databases are competent tools and they have potential for improving the information flow and visibility. These tools should be utilized more extensively inside Cargotec. For example, inventory parameters database can be used as a channel for front line personnel to request central stocking for non-active parts which are critical for their service operations. On the other hand, with product support database, front line could receive valuable information about product and spare part modifications. It is also advisable to arrange possibilities for different units to share information and experiences informally, for example by visiting each other's locations. At the very least, the area sales managers of Central Operations should familiarize themselves with the service business and operations of their sales region and conversely, front line units should be introduced to the common spare part policy and way of working in Cargotec.

One possibility for optimizing inventory assortments in multi-echelon inventory systems is the method of inventory pooling and lateral transshipments. With this method, for example expensive and rare items could be stocked in a predetermined location instead of stocking them in multiple locations and then shipped to other locations when needed. This method is already used at Central Operations echelon.

However, in Cargotec Services there is a policy that basically forbids front line units to exploit lateral transshipments with each other. Thus it is not currently possible to exploit this method properly at front line echelon. Nevertheless, reactive lateral transshipments could be used in some emergency situations, where there is no stock at Central Operations and new parts cannot be delivered from the supplier quickly enough. But this method needs to be operated through coordination of Central Operations' area sales manager. This kind of method is possible after SAP is implemented on large scale because only then Central Operations can see the front line inventories from the system.

7.2. Assessment of the study

This thesis represents a solution to its research problem. However, the thesis concentrates on Cargotec Services' inventory management process merely from the planning perspective. Hence some aspects, such as performance of suppliers and haulers and also operational warehousing, are not included in the examination. Nevertheless, these aspects are in important role when striving for efficient spare part process and when developing the performance of the whole supply chain. For instance, problems and delays in the reception process of purchase orders extend the purchase lead time which results in higher ROPs and safety stocks. Hence, besides streamlining the planning of spare part inventories, Cargotec Services should also measure and develop performance of operational warehousing process. This applies to suppliers and haulers as well. In addition, transportation costs and possible effects on them were not examined in this study. Nevertheless, when streamlining and centralizing front line inventories, the demand for urgent front line deliveries increases which affects on the transportation costs.

The results presented in this thesis must be viewed critically. One reason for this is the fact that the decisions of this case study were based on momentary data. Thus the results would most likely be different when executing the analyses with data of different week or month. This applies for example to local inventory data and the items that had no stock on hand. On another day, the on hand inventory assortment would probably have been different. In addition, the processes and guidelines of the empirical part were formed mainly from information which was acquired by interviews. Because of this, majority of the thesis was compiled based on perceptions and opinions of Cargotec's employees. The current operation structure and used information systems affected on the results as well. Because of the current state of operations, it is not possible or reasonable to design completely new policies based on theory. Hence, the best practices presented in the theoretical part could not be implemented entirely but a combination of theory and existing policies was compiled.

Another point is that the specific decisions, which were made for the example case, are not necessarily suitable for other cases. For instance, when streamlining inventory management of other sales offices, the methods used in this study may not be the most suitable. Cargotec has a multiform history and the company has been composed from many corporate acquisitions. Because of this fact, there are as many ways of thinking and working as there are front line units and this requires case by case examination. Thus, when streamlining inventory management of a front line, it is important to examine first, what is their business like and how they operate. Another significant factor is the location of front line unit and its distance to DC. When streamlining front line inventories, the accessibility and delivery lead time are in vital role.

All in all, because this thesis is a relatively narrow single case study, the findings are company and case-specific which is why the theoretical implications are quite limited. However, the streamlining framework could be utilized in general terms by companies that have similar service networks with global multi-echelon inventory systems. This thesis provides also fairly extensive case description of service operations for further studies and benchmarking.

7.3. Recommendations for further studies

This thesis continued the series of publications that emphasize the need for inventory balancing. The thesis emphasizes especially the rationalizing and unifying of inventory management policies of Cargotec Services. However, the thesis includes only single case at the introduction phase of front line streamlining and SAP implementation. Because of this, the actual results of the corporation wide streamlining are not yet visible. Thus executing further studies is recommended. For example the affect of streamlining on spare part order-to-delivery lead times, customer service level, and customer satisfaction would be interesting research subjects. Especially researching the actual end customer service would give valuable information for the company. When the SAP implementation is completed and level of information transparency is higher, these subjects could be researched in depth.

Another possible area for further study is the XYZ-classification. The classification model should be studied more extensively in an environment of intermittent and low demand. The specific tuning of the classification limits and number of classes in the whole spare part inventory network was not included in this study because of the limited time available. It would be interesting to see what kind of affects for example adding new classes would do for the spare part operations and how the performance could be improved with these fine adjustments.

As mentioned before, transportation costs were excluded from this study, which is a possible area for further study in the case company. It would be interesting to see how the streamlining process affects on the transportation costs when the flow and delivery frequency of items increase. The study could be carried out in Cargotec’s case or even in multiple companies when it would provide more valuable findings.

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Interviewee 1. Manager, Warehousing and Transportation Projects, Metso Minerals Inc. Tampere. 30th March 2012.

Interviewee 2. Manager, Customer Services, Sandvik Mining and Construction. Tampere. 13th April 2012.

Interviewee 3. Purchaser, Services, Front line unit 1 in EMEA-region. Cargotec. 8th March 2012.

Interviewee 4. Supply chain supervisor, Services, Front line unit 1 in EMEA-region. Cargotec. 8th March 2012.

Interviewee 5. Spare parts manager, Services, Front line unit 1 in EMEA-region. Cargotec. 8th March 2012.

Interviewee 6. Supervisor, Parts, Front line unit 2 in EMEA-region. Cargotec. 13th June 2012.

Interviewee 7. Manager, Service support and parts, Front line unit 2 in EMEA-region. Cargotec. 13th June 2012.

Interviewee 8. Director, Services, Cargotec CHS Asia Pacific Pte Ltd. Singapore. 11th April 2012 (by e-mail).

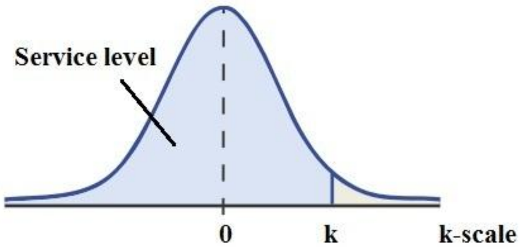
Laine, J. Manager, Parts & Logistics department of Cargotec Services, Cargotec Finland Oy. Tampere. 24th January 2012.

Manninen, M. Purchasing engineer, Parts & Logistics department of Cargotec Services, Cargotec Finland Oy. Tampere. 15th March 2012.

Moilanen, E. Project Manager, Parts & Logistics department of Cargotec Services, Cargotec Finland Oy. Tampere. 7th February 2012.

Uskola, T. Logistics engineer, Parts & Logistics department of Cargotec Services, Cargotec Finland Oy. Tampere. January 2012.

Appendix 1: Correlation of service level and safety factor



k	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998

Service level

(Adapted from Stevenson 2007)

Appendix 2. Inventory parameters database

Example case:

Inventory Parameters Database instructions (1/2):

Inventory Parameters Database instructions (2/2):

Appendix 3. Product support database

Example case:

Appendix 4. Outline of the front line unit interview

1) **Can you first tell something about yourselves?**
   a) For instance education and career background?
2) **Can you introduce your spare part operations?**
   a) Which are the basic operations?
   b) What is the supply chain like and which parties are involved?
   c) Which are your stocking locations?
3) **What kind of customer base you have?**
   a) Customer types and locations?
   b) Which customers are most important ones?
   c) What kind of service contracts you have?
   d) How service factors such as required service level and response time are determined?
4) **What kind of inventory management policies and methods you have?**
   a) What kind of item classification do you use?
      - Which criteria do you use and how many segments you have?
      - Do you define active and non-active items?
      - How often is the classification updated?
   b) Which factors determine part criticality?
      - Can you give examples of critical parts?
   b) How stock levels and ordering are controlled?
      - How is safety stock determined?
      - How are order quantities determined?
      - How are reorder points determined?
      - Or do you use periodic review policy?
5) **What kind of KPIs do you monitor in inventory management?**
   a) How are customer service and inventory costs measured?
   b) How is item movement measured?
   c) How often are these measurements performed?
6) **What kind of follow-up tools do you use?**
   a) Such as reports and spreadsheets?
   b) How often are these tools updated or checked?
7) **What are the biggest challenges in your spare part inventory management?**
8) **How could Central Operations support your business?**
9) **How would you develop the spare part supply chain?**
10) **How would you develop the spare part inventory management?**
11) **Do you want to pass on any requests or comments from your customers?**
12) **Do you have any other comments?**

Appendix 5. Outline of the benchmarking interview

1) **Can you first tell something about yourselves?**
   a) For instance education and career background?
2) **Can you introduce your spare part operations?**
   a) Which are the basic operations?
   b) What is the supply chain like? (stocking locations and levels, involved parties)
3) **What kind of inventory management policies you have?**
   a) What kind of item classification do you use? (used criteria, different segments)
   b) How is item criticality defined?
   c) How are different segments managed?
   d) How do you decide where to hold stock (between different stocking levels)?
      - What are the criteria for these decisions?
      - Who makes the decisions?
      - How service contracts affect these decisions?
      - How contract requirements are taken into account in inventory management?
4) **What kind of KPIs do you monitor in inventory management?**
5) **What kind of follow-up tools do you use?**
6) **What do you think are the biggest challenges in your spare part inventory management?**
7) **Do you have any other comments?**

Appendix 6. Results of the item transaction analysis (12 months)

Frequency-specific results:

Table A6.1.				
Frequency	**Items**	**Transactions**	**Sales volume**	**COGS**
1	x	x	x €	x €
2	x	x	x €	x €
3	x	x	x €	x €
4	x	x	x €	x €
5	x	x	x €	x €
6	x	x	x €	x €
7	x	x	x €	x €
8	x	x	x €	x €
9	x	x	x €	x €
10	x	x	x €	x €
11	x	x	x €	x €
12	x	x	x €	x €
13	x	x	x €	x €
14	x	x	x €	x €
15	x	x	x €	x €
16	x	x	x €	x €
17	x	x	x €	x €
18	x	x	x €	x €
19	x	x	x €	x €
20-29	x	x	x €	x €
30-39	x	x	x €	x €
40-49	x	x	x €	x €
≥ 50	x	x	x €	x €

Cumulative results in values (the figure in the upper cell of table A6.1. is added to the lower cell):

Table A6.2.				
Frequency	**Items**	**Transactions**	**Sales volume**	**COGS**
1	x	x	x €	x €
2	x	x	x €	x €
3	x	x	x €	x €
4	x	x	x €	x €
5	x	x	x €	x €
6	x	x	x €	x €
7	x	x	x €	x €
8	x	x	x €	x €
9	x	x	x €	x €
10	x	x	x €	x €
11	x	x	x €	x €
12	x	x	x €	x €
13	x	x	x €	x €
14	x	x	x €	x €
15	x	x	x €	x €
16	x	x	x €	x €
17	x	x	x €	x €
18	x	x	x €	x €
19	x	x	x €	x €
20	x	x	x €	x €
30	x	x	x €	x €
40	x	x	x €	x €
50	x	x	x €	x €

Cumulative results in percentage of the total amount:

Table A6.3.				
Frequency	**Items**	**Transactions**	**Sales volume**	**COGS**
1	x %	x %	x %	x %
2	x %	x %	x %	x %
3	x %	x %	x %	x %
4	x %	x %	x %	x %
5	x %	x %	x %	x %
6	x %	x %	x %	x %
7	x %	x %	x %	x %
8	x %	x %	x %	x %
9	x %	x %	x %	x %
10	x %	x %	x %	x %
11	x %	x %	x %	x %
12	x %	x %	x %	x %
13	x %	x %	x %	x %
14	x %	x %	x %	x %
15	x %	x %	x %	x %
16	x %	x %	x %	x %
17	x %	x %	x %	x %
18	x %	x %	x %	x %
19	x %	x %	x %	x %
20	x %	x %	x %	x %
30	x %	x %	x %	x %
40	x %	x %	x %	x %
50	x %	x %	x %	x %

Appendix 7. On hand inventory with 12-month sales history

Frequency-specific results:

Frequency	Inventory value	Items	Trans-actions	Sales volume	COGS
0	x €	x	-	-	-
1	x €	x	x	x €	x €
2	x €	x	x	x €	x €
3	x €	x	x	x €	x €
4	x €	x	x	x €	x €
5	x €	x	x	x €	x €
6	x €	x	x	x €	x €
7	x €	x	x	x €	x €
8	x €	x	x	x €	x €
9	x €	x	x	x €	x €
10	x €	x	x	x €	x €
11	x €	x	x	x €	x €
12	x €	x	x	x €	x €
13	x €	x	x	x €	x €
14	x €	x	x	x €	x €
15	x €	x	x	x €	x €
16	x €	x	x	x €	x €
17	x €	x	x	x €	x €
18	x €	x	x	x €	x €
19	x €	x	x	x €	x €
20-29	x €	x	x	x €	x €
30-39	x €	x	x	x €	x €
40-49	x €	x	x	x €	x €
≥ 50	x €	x	x	x €	x €

Appendix 8. Summary of the inventory analysis

Transaction history data from 12 months:

Class	Items	%	Transactions	%	Sales volume	%	COGS	%
X (≥12)	**x**	**x**	**x**	**x**	**x €**	**x**	**x €**	**x**
A	x	x	x	x	x €	x	x €	x
B	x	x	x	x	x €	x	x €	x
C	x	x	x	x	x €	x	x €	x
Y (6-11)	**x**	**x**	**x**	**x**	**x €**	**x**	**x €**	**x**
A	x	x	x	x	x €	x	x €	x
B	x	x	x	x	x €	x	x €	x
C	x	x	x	x	x €	x	x €	x
Z1 (3-5)	**x**	**x**	**x**	**x**	**x €**	**x**	**x €**	**x**
A	x	x	x	x	x €	x	x €	x
B	x	x	x	x	x €	x	x €	x
C	x	x	x	x	x €	x	x €	x
Z2 (1-2)	**x**	**x**	**x**	**x**	**x €**	**x**	**x €**	**x**
A	x	x	x	x	x €	x	x €	x
B	x	x	x	x	x €	x	x €	x
C	x	x	x	x	x €	x	x €	x
Total	x		x		x €		x €	

Transaction history data combined with on hand inventory data:

Class	Items	%	Transactions	%	Sales volume	%	COGS	%	Inventory value	%	Inv. turnover
X (≥12)	**x**	**x**	**x**	**x**	**x €**	**x**	**x €**	**x**	**x €**	**x**	**x**
A	x	x	x	x	x €	x	x €	x	x €	x	x
B	x	x	x	x	x €	x	x €	x	x €	x	x
C	x	x	x	x	x €	x	x €	x	x €	x	x
Y (6-11)	**x**	**x**	**x**	**x**	**x €**	**x**	**x €**	**x**	**x €**	**x**	**x**
A	x	x	x	x	x €	x	x €	x	x €	x	x
B	x	x	x	x	x €	x	x €	x	x €	x	x
C	x	x	x	x	x €	x	x €	x	x €	x	x
Z1 (3-5)	**x**	**x**	**x**	**x**	**x €**	**x**	**x €**	**x**	**x €**	**x**	**x**
A	x	x	x	x	x €	x	x €	x	x €	x	x
B	x	x	x	x	x €	x	x €	x	x €	x	x
C	x	x	x	x	x €	x	x €	x	x €	x	x
Z2 (1-2)	**x**	**x**	**x**	**x**	**x €**	**x**	**x €**	**x**	**x €**	**x**	**x**
A	x	x	x	x	x €	x	x €	x	x €	x	x
B	x	x	x	x	x €	x	x €	x	x €	x	x
C	x	x	x	x	x €	x	x €	x	x €	x	x
N (0)	**x**	**x**	**-**	**-**	**-**	**-**	**-**	**-**	**x €**	**x**	**x**
Total	x		x		x €		x €	x	x €	x	x

Appendix 9. On hand inventory with 24-month sales history

Frequency-specific results:

Frequency	Inventory value	Items	Trans-actions	Sales volume	COGS
0	x €	x	-	-	-
1	x €	x	x	x €	x €
2	x €	x	x	x €	x €
3	x €	x	x	x €	x €
4	x €	x	x	x €	x €
5	x €	x	x	x €	x €
6	x €	x	x	x €	x €
7	x €	x	x	x €	x €
8	x €	x	x	x €	x €
9	x €	x	x	x €	x €
10	x €	x	x	x €	x €
11	x €	x	x	x €	x €
12	x €	x	x	x €	x €
13	x €	x	x	x €	x €
14	x €	x	x	x €	x €
15	x €	x	x	x €	x €
16	x €	x	x	x €	x €
17	x €	x	x	x €	x €
18	x €	x	x	x €	x €
19	x €	x	x	x €	x €
20-29	x €	x	x	x €	x €
30-39	x €	x	x	x €	x €
40-49	x €	x	x	x €	x €
≥ 50	x €	x	x	x €	x €